# Soil Investigation and Human Health Risk Assessment for the Rodney Street Community, Port Colborne

October 2001

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Ministry of the
Environment

# Soil Investigation and Human Health Risk Assessment for the Rodney Street Community, Port Colborne

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# Executive Summary

## Conclusions

The Ministry of the Environment's soil investigation and human health risk assessment report for the Rodney Street community has determined that elevated nickel and lead soil contamination on some properties warrants action. The report provides a comprehensive soil investigation and human health risk assessment that examined about 1,500 soil samples to determine the human health risk posed by metal and arsenic levels in surface soil in the Rodney Street community. The health risk assessment reviewed concentrations of seven metals and arsenic and has proposed:

- an intervention level of 8,000 parts per million[1] be set for soil-nickel. The intervention level for nickel requires action through remediation of soil.
- an intervention level of 1,000 ppm for lead for play areas on residential properties or in public areas **covered by sod or grass** to which children have access (**the bare soil** intervention level for lead is 400 ppm for these areas). The intervention levels for lead require action through followup by individual residents to reduce personal exposure to lead.

The assessment also concluded that no action for the remaining five metals (antimony, beryllium, cadmium, copper, cobalt) and arsenic in soil is required.

In carrying out the investigation and assessment, the Ministry of the Environment identified soil-nickel levels in excess of 8,000 ppm, in at least one composite sample, in the first 30 cm of soil at 25 properties. The soil-nickel has resulted from historical emissions from Inco Limited (Inco). The ministry also found lead levels in excess of 1,000 ppm at eleven properties, including two of the 25 properties elevated soil-nickel levels. These soil-lead levels are typical in older, established urban neighborhoods and result from the historical use of lead based paints, leaded gasoline and discarded lead-acid batteries. The lead levels are not attributed to Inco emissions.

The report's key findings for the Rodney Street community include:

1. A soil-nickel intervention level has been proposed to protect toddler-aged children;
2. Soil-nickel levels in the community should not pose any immediate or long-term risks to other age groups;
3. Twenty-five properties have at least one composite soil sample that is in excess of 8,000 ppm for nickel;
4. Intervention levels for lead have been proposed to protect children;

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[1] Also referred to as ppm, µg/g, micrograms per gram, or, millionths of a gram.

5. Eleven properties have at least one composite soil sample that is in excess of 1,000 ppm for lead; including two of the 25 properties identified as having high soil-nickel concentrations;

6. The soil levels of antimony, beryllium, cadmium, copper, cobalt and arsenic were below the level of concern and therefore no action is needed.

**Human Health Risk Assessment**

The Ministry of the Environment has conducted a human health risk assessment of the elevated concentrations of seven metals (antimony, beryllium, cadmium, cobalt, copper, lead, nickel) and arsenic found in the surface soils of the Rodney Street community. The health risk assessment was peer reviewed by an international panel of experts. The panel included recognized North American and European experts from the fields of: human health, nickel toxicology, risk assessment and metal bioaccessibility. The peer review experts were:

- Dr. Ambika Bathija (Washington, D.C.), affiliated with the United States Environmental Protection Agency
- Dr. Lynne Haber (Cincinnati, Ohio), affiliated with the Toxicology Excellence for Risk Assessment
- Dr. Robert Jin (Toronto, Ontario), affiliated with the Ontario Ministry of Health and Long-Term Care
- Dr. Tor Norseth (Oslo, Norway), affiliated with the Norwegian National Institute of Occupational Health
- Dr. Rosalind Schoof (Seattle, Washington), affiliated with Gradient Corporation
- Dr. John Wheeler (Atlanta, Georgia), affiliated with the Agency for Toxic Substances and Disease Registry

A human health risk assessment can be triggered when contaminants are found in a community at levels above the ministry's *Guideline for Use at Contaminated Sites in Ontario (1997)*. The multimedia approach to health risk assessment examines total exposure to contaminants through a number of possible pathways, such as the air we breathe, the soil we may incidentally ingest, the water we drink and the food we eat.

This human health risk assessment has assessed exposure to selected contaminants in the Rodney Street community. It has proposed exposure (or soil concentration) levels that maintain human exposure below health protection criteria. The assessment has also proposed levels to remediate soil and to reduce exposure to contaminated soil. The results of the health risk assessment have been provided to the Regional Niagara Public Health Department and will be considered in the health study for the Eastside community.

## Nickel

The health risk reassessment proposes a soil-nickel intervention level of 8,000 ppm to protect toddler-aged children. The report finds that soil-nickel levels should not pose immediate or longer-term risks to other age groups. This intervention level has been developed to protect against adverse health effects from exposure to nickel. The report reviewed the toxicological basis for health protection criteria that have been developed by key agencies responsible for health and environmental protection. These health-based criteria are developed to provide protection for the most sensitive adverse effects found in human or animal studies. For nickel, the most sensitive adverse effects which could be identified are reproductive effects and reduced organ weight in animals.

In its human health risk assessment, the ministry considered contaminant exposures from a variety of sources including: indoor and outdoor air; soil and dust; food from the supermarket and home gardens; and the municipal drinking water supply. To protect residents, and especially toddlers, the soil-nickel intervention level was developed to ensure that all of the above nickel exposures did not exceed a toxicological value that is well below any potential health risk.

The ministry's *Guideline for use at Contaminated Sites in Ontario* (1997) references a human health value for nickel of 310 ppm. However, the 310 ppm value is only used for a generic cleanup of soil or as a trigger value above which soil-nickel levels require a detailed, scientific, human health risk assessment. Soil levels above 310 ppm do not necessarily constitute a health risk. The figure of 310 ppm should also not be used for the Community Based Risk Assessment that is being done for the broader community. This human health risk assessment has determined the potential for adverse effects based on estimated exposure to measured levels of contamination in the Rodney Street community.

It is noted in the report that there are inadequate scientific data to determine if the Rodney Street community soil intervention level for nickel is protective of nickel dermatitis for sensitized individuals, or for people who could become sensitized to nickel. Health studies underway in the Port Colborne community will test people for nickel contact dermatitis.

In the case of inhaled nickel, lifetime cancer risks were determined to be in the one-in-one-hundred-thousand ($10^{-5}$) lifetime risk range. These estimates were based on health studies of workers exposed to nickel refinery dusts which include nickel oxide. This risk range is considered very low.

## Lead

Lead in soil has long been recognized as posing potential risk, particularly to younger children up to five years of age, who were considered the most sensitive to exposures for direct soil/dust ingestion.

Average soil-lead levels in the Rodney Street community (average of 204 ppm in surface samples) are similar to those expected for other urban residential sites in Ontario. As a result, estimated exposures (and hence blood lead levels) are predicted to be similar to those for other urban Ontario populations[2].

It is prudent, however, to conclude that in the 11 properties with reported soil-lead levels higher than 1,000 ppm there may be some possibility for higher blood lead levels in children who routinely play in these areas.

As a result, the report proposes an intervention level of 1,000 ppm for lead for play areas on residential properties or in public areas **covered by sod or grass** to which children have access (**the bare soil** intervention level for lead is 400 ppm for these areas). Residents at properties exceeding 1,000 ppm lead in soil were advised in March 2001 to avoid contact with soil and to not consume vegetables from backyard gardens. Additional ways to reduce exposure to the lead in soil are presented in the ministry's fact sheet, *"Frequently Asked Questions About Lead Contamination"*.

## Arsenic

People everywhere in North America are exposed to low levels of arsenic in the environment. Exposures can occur by a number of different pathways including normal diet and drinking water. The measured soil-arsenic levels in the Rodney Street community were compared to the levels found in other Ontario communities with elevated levels of soil-arsenic. In the case of these communities, no adverse health effects were predicted to be associated with the arsenic in the soil.

This report concludes that the measured levels of arsenic in the Rodney Street community soils are unlikely to pose an undue health risk to residents of this community based on consideration of: the measured availability of the arsenic in these soils; comparison to typical levels elsewhere; and knowledge of health study outcomes involving arsenic soil exposure in other Ontario communities.

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[2] The Regional Niagara Public Health Department (RNPHD) indicates that it undertook ten blood lead screening test clinics between April and June 2001, for residents living or frequently spending time in the area. Pregnant women, women of reproductive age and children under seven, were strongly encouraged to participate in the blood lead level screening tests. Over 1,000 people participated in the blood lead level screening tests and the results showed that blood lead levels are low and similar to those found elsewhere in the province. Further, there was no correlation demonstrated between properties with elevated soil-lead levels and elevated blood lead levels in residents.

The RNPHD blood lead screening report had two conclusions. Children under seven years and pregnant women in the Eastside community are not at increased risk of lead exposure as compared to other communities in Ontario, even considering the localized elevated soil-lead levels. Therefore, no immediate intervention is required regarding lead remediation in the Eastside community.

The RNPHD also concluded that although the results appear reassuring and can be applied in general to the whole population in the Eastside Community, pregnant women or children under age seven who live in the Eastside community and who were not tested during this study are encouraged to do so as part of Phase Three of the Eastside Community Health Study.

### Antimony, Beryllium, Cadmium, Cobalt and Copper

Taking the same approach as used for nickel, estimates were modeled using the maximum reported levels of each metal in the Rodney Street community surface soil and backyard produce, Port Colborne municipal drinking water, ambient air and supermarket food.

For the metals antimony, beryllium, cadmium, cobalt and copper, estimated total daily intakes for all age groups were well below stringent oral or breathing exposure limits from major recognized jurisdictions, such as, the US Environmental Protection Agency, World Health Organization and Health Canada. No adverse health effects are anticipated to result from exposure to antimony, beryllium, cadmium, copper or cobalt, in soils in the Rodney Street community.

Therefore, soil intervention levels were not developed and no action is required for these metals for the Rodney Street community.

### Background

From 1918 to 1984 Inco operated a nickel refinery in the city of Port Colborne. Between the years 1972 and 1991, the Ontario Ministry of the Environment conducted numerous investigations to document the impact of Inco's emissions on soil and vegetation in and around Port Colborne. These investigations concluded that emissions from 66 years of nickel refining had resulted in heavy metal soil contamination in various locations throughout the Port Colborne area. Nickel, copper and cobalt concentrations in surface soil (0 to 5 cm depth) were elevated in residential communities adjacent to Inco and for a considerable distance downwind (east-northeasterly) of the refinery to levels which could or did cause injury to vegetation (phytotoxicity). Generally, the vegetation impacts noted were the crops of muck farms and to silver maple trees.

With the benefit of hindsight, it can be said that these levels for nickel, copper and cobalt concentrations are consistently and substantially elevated above the ministry's effects-based soil guidelines for phytotoxicity published in the ministry's *Guideline for Use at Contaminiated Sites in Ontario* (1997) over a large area. By contrast, the soil arsenic, zinc and selenium levels found in those investigations exceed the Guideline's background ranges in a few areas, and even less frequently exceed effects-based guidelines for phytotoxicity.

As noted above, the ministry's effects-based guideline criteria for nickel, copper, cobalt, arsenic and zinc are all based on phytotoxicity (injury to vegetation). The Guideline's criterion for selenium is based on the protection of grazing animals. Numerous ministry studies conducted on Port Colborne farms in the 1970s and 1980s documented toxicity to agricultural crops as a result of ambient air $SO_2$ fumigations and heavy metal soil contamination. Up to 1991 the highest soil-nickel concentration that could be proven to exist through repeat sampling in the Port Colborne area was 9,750 µg/g. A human health risk assessment using this maximum soil-nickel level was published by the ministry and Regional Niagara Public Health Department in 1997. It was concluded at the time that based on a multi-media assessment of potential risks, no adverse health effects are anticipated to result from exposure to nickel, copper, or cobalt, in soils in the Port Colborne community.

Additional extensive soil sampling was conducted by the ministry in the City of Port Colborne and the surrounding area in 1998 and 1999 and demonstrated that soil-nickel concentrations exceed the ministry's soil background-based guideline up to 28 km downwind of the refinery, covering a 345 $km^2$ area of the Niagara peninsula. Furthermore, soil-nickel levels exceeded the ministry's effects-based guideline for phytotoxicity, for a distance of up to 3 km downwind of Inco over an area of almost 29 $km^2$. In addition, copper and cobalt also exceed their corresponding effects-based soil guidelines in smaller areas of the community, mainly immediately east, north, and northeast of the refinery.

In September 2000, soil-nickel levels from a single property on Rodney Street were found to exceed the soil-nickel level used in the 1997 health risk assessment. This result caused the ministry to sample and analyze soil from 17 additional properties, on or in the vicinity of Rodney Street. Preliminary results of the additional sampling indicated that surface soil-nickel levels ranged up to 17,000 ppm, and that the soil-metal levels were extremely variable among properties. As a result, in November 2000, the ministry sampled soil from residential properties south of Louis Street to Rodney Street and east of the Welland Canal to Davis Street, to determine the extent of this contamination. Between April 25 and May 5, 2001 the ministry sampled surface soil from additional residential properties as per the requests from the City and residents. In all, more than 1,500 soil samples were collected from nearly 200 properties.

The findings from the extensive soil surveys triggered the ministry to undertake a human health risk assessment of metals and arsenic found at elevated concentrations in the soil. The assessment concluded that soil-nickel and lead levels warranted further action on some properties. The assessment was conducted and released on March 30, 2001 and accompanied a Notice of Intent to Order Inco to clean up 16 properties with soil concentrations over 10,000 ppm which was placed on the Environmental Registry for a 30-day public comment period. During this consultation period the ministry identified a calculation error in the report and received comments on the report that ranged from the ministry being too stringent to not being stringent enough in some of the values it used and the approach it took in developing the intervention level for nickel. In response to these developments, and to enhance the quality and accuracy of its report, the ministry:

- initiated new laboratory tests to better define the form of nickel found in the soil and better estimate the amount of nickel that could be absorbed through the stomach; and
- commissioned an expert, international peer review. The panel of experts included recognized experts from the fields of: human health, nickel toxicology, risk assessment and metal bioaccessibility.

## Soil Investigation Results

This section of the report was revised with expert advice from outside the ministry. Advice was provided in areas of environmental sciences, soil sampling and terrestrial investigations and statistical methods of data analysis.

## Extent and Severity

Ministry studies have shown elevated soil-metals levels around Port Colborne and in residential communities adjacent to the Inco site. Because the community is in close proximity to the refinery, soil would have received stack emissions as well as extensive fugitive emissions, both of which would have been particularly significant early in Inco's operating history.

The ministry employed a sampling strategy based upon well established scientific principles. The front, back or side yard could have been sampled depending on the size and nature of each yard on each property. The strategy also included intensive quality control with the taking of duplicate and triplicate soil core samples from selected properties. The strategy was designed to allow the ministry to describe the specific soil levels for each property and to also define with precision, the soil-metal level variability that is present in the community. This information was used in combination with the human health risk assessment to establish a soil intervention level for nickel.

The soil-nickel concentration averaged about 2,500 ppm while the single highest concentration was 17,000 ppm. Ninety per cent of the soil-nickel concentrations for all samples collected in the Rodney Street community are below 5,600 ppm. Twenty-five of the properties sampled had at least one soil result that exceeded the proposed soil-nickel intervention level developed to be protective of toddler-aged children and warrant further action.

Soil-metal concentrations on average increased with depth to a maximum of between 10 cm to 20 cm, the limit of the majority of residential sampling performed. Based on trench digging, metal concentrations above the proposed soil-nickel intervention level are less likely to be found deeper than 30 cm on most residential properties within the community.

## Sources and Mechanisms

Based upon the extensive surface soil sampling investigation and laboratory testing, elevated soil levels for nickel, copper, and cobalt in the Rodney Street community are considered directly related to Inco. The company has acknowledged this in an open letter to the public (December 2000).

Soil-arsenic levels observed are considered principally Inco related, however emissions from the Algoma Steel/Canada Furnace blast furnace and steel mill that operated from 1913 to 1977 were probably a secondary source and likely contributed to the elevated soil-arsenic levels on some properties in the Rodney Street community.

Soil-lead levels observed are randomly scattered in the Rodney Street community. This is considered typical of domestic residential lead sources and is not attributed to Inco emissions. The erosion and flaking of old lead-based paint from exterior structures such as house and shed walls, porches, fences, poles, and playground equipment is a common source of soil-lead contamination in older urban communities. The soil-lead levels found in the Rodney Street community are not unusual, either in extent or concentration, relative to other similar, older urban communities in Ontario.

Levels of cadmium, chromium, copper, barium, and zinc in soil were often associated with higher lead levels. Along with lead, these elements were common pigment, anti-mildew, or anti-fungal additives in old exterior paint and are frequent co-contaminants in residential soil. Lead and antimony levels observed in the soil are an indication that batteries may have been stored or disposed of on the property, whereas lead, barium and zinc soil contamination is a signature of lead-based paint.

With the exception of one property where elevated beryllium levels were concurrent with high lead and other heavy metals, the marginally elevated soil-beryllium concentrations across the Rodney Street community are likely related to the presence of slag and local shale deposits. Emissions from Algoma may have contributed to the marginally elevated soil-beryllium levels in the Rodney Street community.

Considerable variability in soil-contaminant levels was evident between adjacent properties. This "patchwork" pattern of high-and-low soil contamination on neighbouring lots is likely related to property maintenance and landscaping. Adding topsoil or mulch, re-sodding, building, and cultivating gardens are landscaping practices that, over time, tend to cover or dilute contaminants that are predominantly present in the surface soil. It also indicates that the source of the soil contamination is likely atmospheric and that with recent deposition substantially decreased, newly landscaped properties have not become re-contaminated to the levels of undisturbed properties.

Visual and test findings from three trench samples indicated that fill materials may have contributed to higher metal levels in soils in the south east corner of Rodney Street. However the same information from six other trenches in the community indicated that the higher levels of metals in soil were to be found in the upper layers, supporting the likelihood that metals in soil in the wider community resulted from atmospheric deposition.

Chemical Composition of Nickel

The form of nickel in the soil can have an important impact on its availability and its toxicity for both the natural ecosystem and human health.

The predominant form of nickel in the soil in the Rodney Street community is nickel oxide (80% of the total nickel, on average). This is consistent with known emissions from the metallurgical process employed by Inco, especially in its historic operations. This is also acknowledged by Inco.

After the shutdown of the refinery in 1984, nickel injury on sensitive species of vegetation has rarely been observed in Port Colborne. This corroborates the low soil-nickel plant bioavailability results (the ability of plants to absorb nickel from the soil) and suggests that most of the nickel injury observed on vegetation up to 1984 was likely from deposition and absorption of nickel from the ambient air and not from uptake of soluble nickel from nickel-contaminated soil by plants. There were no symptoms of nickel related injury to plants observed in the community during the most recent investigations.

## Study Participants

The Rodney Street community study involved many scientists and technicians from the Ministry of the Environment. The following staff of the Standards Development Branch, Ecological Standards and Toxicology Section participated in sample collection and sample processing: Marius Marsh, Murray Dixon, Bill Gizyn, Bob Emerson, Ron Hall, Danuta Roszak, Deborah Terry, Melanie Appleton, Richard Chong-Kit, Mike Mueller, and Al Kuja. Randall Jones co-ordinated the geo-referencing of the soil samples, managed the soil data base, and prepared the contaminant contour maps. Dave McLaughlin was the principal author of Part A of the report.

The Human Health Risk Assessment (Part B) was conducted by toxicologists of the Standards Development Branch, Human Toxicology and Air Standards Section. Brendan Birmingham co-ordinated this effort and is the principal author of Part B of the report. Contributing toxicologists included Scott Fleming, Satish Deshpande, Marco Pagliarulo and Audrey Wagenaar. Elliot Sigal and Glenn Ferguson of Cantox Environmental Inc., and Bryan Leece of Dillon Consulting Ltd. provided technical assistance.

Laboratory Services Branch personnel provided critical laboratory support. Liz Pastorek administered the contract for the private laboratory that conducted the soil analysis. Tender evaluation was conducted by Peter Drouin. The initial quality control check was handled by Sathi Seliah. Rusty Moody and Jim Howden provided data monitoring and data management duties. The in-house laboratory analysis required to ensure data quality was conducted by Lian Liu and Julie Uzonyi (ICO - metals) and Hung Sing Chiu and Regina Pearce (hydrides).

Jacques Whitford Environmental Limited provided recent residential vegetable garden produce and garden soil data for both the Rodney Street community and Port Colborne in general, and air monitoring data for selected schools.

Paul Nieweglowski and Bob Slattery of the Niagara District Office provided liaison between the Ministry's Operations Division and the Environmental Science and Standards Division. Rick Day was the communications officer.

Neil Buonocore and Frank Dobroff of the Ministry's West Central Region Technical Support installed and operated the air quality monitor in the Rodney Street ball park.

Barry Zajdlik of Zajdlik & Associates provided statistical analysis of the soil data base and the soil sampling procedure.

Ron Pearson of Barenco Inc. and Tom Hutchinson of Trent University provided a critical review of the *Part A Soil Investigation* component of the report.

The human health risk assessment was peer reviewed by an international panel of experts. The panel included recognized North American and European experts from the fields of : human health, nickel toxicology, risk assessment and metal bioaccessibility. The peer review experts were:

- Dr. Ambika Bathija (Washington, D.C.), affiliated with the United States Environmental Protection Agency
- Dr. Lynne Haber (Cincinnati, Ohio), affiliated with the Toxicology Excellence for Risk Assessment
- Dr. Robert Jin (Toronto, Ontario), affiliated with the Ontario Ministry of Health and Long-Term Care
- Dr. Tor Norseth (Oslo, Norway), affiliated with the Norwegian National Institute of Occupational Health
- Dr. Rosalind Schoof (Seattle, Washington), affiliated with Gradient Corporation
- Dr. John Wheeler (Atlanta, Georgia), affiliated with the Agency for Toxic Substances and Disease Registry

Dr. Robert Willes of Cantox Environmental Inc. was the facilitator of the expert panel consensus meeting, and prepared the expert Panel consensus report.

Comments were also received from Health Canada and the Regional Niagara Public Health Department which were considered in this report.

Samir Konar provided an external editorial review. Mel Plewes of the Ecological Standards and Toxicology Section provided internal document review.

Overall project management and coordination was provided by Jim Smith, George Crawford, Dale Henry, Dave McLaughlin, Murray Dixon, Marny Paget and Paul Nieweglowski.

# Part A

## Soil Investigation

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## 1.0 Introduction

The Ministry's report entitled ***Soil Investigation and Human Health Risk Assessment for the Rodney Street Community, Port Colborne: October 2001***, has two parts. ***Part A*** describes the results of an extensive soil sampling program in the Rodney Street community of Port Colborne. ***Part B*** is a human health risk assessment. The soil chemical data described in Part A were the environmental contaminants assessed by the health risk assessment described in Part B. For the purpose of Part A and Part B of this report, the Rodney Street community in Port Colborne is defined as the residential area east of the Welland Canal to the International Nickel Company Ltd. (Inco) refinery and south of Louis Street to Rodney Street. This area is also sometimes referred to as the *Eastside community*.

### 1.1 Objectives of Part A

1) to determine the extent and severity of soil metal and arsenic contamination in the Rodney Street community of Port Colborne;

2) to characterize soil metal and arsenic contamination in the Rodney Street community;

3) to determine to the extent possible the source(s) of the soil metal and arsenic contamination in the Rodney Street community; and

4) to determine to the extent possible the mechanism(s) of soil metal and arsenic contamination in the Rodney Street community.

## 2.0 Scope of the Study

The objective of the sampling program was to obtain data that was representative of the over-all contaminant levels of the sampled yards and would therefore be indicative of the environmental exposure that a resident would receive from long term use of the property. This representative data was required for the human health risk assessment (Part B of this report). The risk assessment process integrates the soil chemical data to determine what the over-all exposure would be for people using the entire property for a lifetime. The scope of the sampling program was not to exhaustively characterize the contaminant status of all possible sample sites on every yard of every residential property. The sampling program is described in more detail in Section 5.0 of Part A.

The soil sampling conducted in the Rodney Street community is not necessarily the only sampling that would be conducted to characterize the contaminant status of a particular property. If the soil contaminant levels on a property exceed the risk-based soil intervention level determined by the Ministry's health risk assessment in Part B of this report, the Ministry may order the source of the contamination to conduct additional or more detailed sampling as a part of a remediation strategy for the property. This sampling would be conducted according to the Ministry's *Guideline for Use at Contaminated Sites in Ontario* (MOE,1997).

## 3.0 Background

From 1918 to 1984, the International Nickel Company Limited (Inco) operated a nickel refinery in the city of Port Colborne. Between the years 1972 and 1991, the Ontario Ministry of the Environment (MOE, or the Ministry) conducted numerous investigations to document the impact of Inco's emissions on soil and vegetation in and around Port Colborne. These investigations concluded that emissions from 66 years of nickel refining had resulted in heavy metal soil contamination in various locations throughout the Port Colborne area. Nickel, copper and cobalt concentrations in surface soil (0-5 cm depth) were elevated in residential communities adjacent to Inco and for a considerable distance downwind (east-northeasterly) of the refinery to levels which could or did cause injury to vegetation (phytotoxicity). Generally, the vegetation impacts noted were to farm crops east of Inco and to silver maple trees east of the canal and south of Highway 3. Silver maple is a species of tree that is particularly sensitive to many pollutants, including nickel.

With the benefit of hindsight (MOE soil guidelines were not available previous to 1996), we can say that the levels of nickel, copper, and cobalt identified in soil over a large area of Port Colborne as a result of these early investigations are consistently and substantially elevated above MOE effects-based soil guidelines for phytotoxicity published in Table A of the MOE's *Guideline* (1997). By contrast, the soil arsenic, zinc, and selenium levels found in those investigations exceed normal Ontario Table F (MOE,1997) background ranges in a few areas, and even less frequently exceed Table A effects-based guidelines for phytotoxicity (arsenic and zinc) and effects on grazing animals (selenium).

As noted above, the MOE Table A effects-based guideline criteria for nickel, copper, cobalt, arsenic and zinc are all based on phytotoxicity (injury to vegetation). The Table A criterion for selenium is based on the protection of grazing animals. Numerous MOE studies conducted on Port Colborne farms in the 1970s and 1980s documented toxicity to agricultural crops as a result of ambient air $SO_2$ fumigations and heavy metal soil contamination (MOE,1977; MOE,1978; MOE,1980; MOE,1983). Up to 1991 the highest soil nickel concentration that could be proven to exist through repeat sampling in the Port Colborne area was 9,750 µg/g (McLaughlin and Bisessar 1994). A human health risk assessment using this maximum soil nickel level was published by the MOE and Regional Niagara Public Health Department in 1997. It was concluded that based on a multi-media assessment of potential risks, no adverse health effects are anticipated to result from exposure to nickel, copper, or cobalt, in soils in the Port Colborne area (Leece and Rifat 1997).

Additional extensive soil sampling was conducted by the MOE in the City of Port Colborne and the surrounding area in 1998 and 1999 and demonstrated that soil nickel concentrations exceed the MOE Table F soil background-based guideline of 43 µg/g up to 28 km downwind of the refinery, covering a 345 km$^2$ area of the Niagara peninsula (Kuja et al., 2000a; Kuja et al., 2000b). Furthermore, soil nickel levels exceeded the MOE Table A effects-based guideline of 200 µg/g for phytotoxicity for a distance of up to 3 km downwind of Inco over an area of almost 29 km$^2$. In addition, copper and cobalt also exceed their corresponding effects-based Table A soil guidelines in smaller areas of the community, mainly immediately east, north, and northeast of the refinery. The derivation and significance of the MOE soil guidelines are described in Section 4.0 and Appendices 1 and 2.

MOE surface soil sampling conducted in 1991 in the vicinity of the Rodney Street community immediately west and northwest of Inco found that soil nickel concentrations in the general area ranged from about 2,000 µg/g to about 4,000 µg/g (McLaughlin and Bisessar, 1994). However, this soil sampling was incidental to a study of general phytotoxicity impacts to agricultural areas of Port Colborne focussing on areas where earlier work had indicated both high soil concentrations and vegetation impacts. No properties on Rodney Street itself were sampled in these early Ministry investigations. As a result, very few surface soil samples were collected and little depth sampling (greater than 5 cm) was done in this part of Port Colborne (the highest soil nickel concentration at 5 - 10 cm was 2,750 µg/g). Concentrations in this range were confirmed by repeated sampling over several years, and so were believed by the Ministry to represent soil metal levels in urban areas of Port Colborne.

During a public information forum held in January 2000 at the Port Colborne city hall, a resident of Rodney Street requested that the MOE sample soil on his property. MOE Phytotoxicology scientists sampled the front and back yards of the property in June 2000. Analysis of the soil samples revealed that soil nickel concentrations at depth (10 - 15 cm) were much higher (~14,000 µg/g) than previously believed to be present in this part of Port Colborne. In addition, soil copper, cobalt, arsenic, lead, and zinc concentrations at depth also exceeded their respective MOE Table A effects-based guidelines. MOE human health toxicologists conducted a screening level risk assessment on the new soil data and determined that the health-based nickel reference dose was exceeded for the maximum nickel concentration found in the front yard of this Rodney Street property. The human health reference dose calculations incorporate considerable safety factors, and although an exceedence of the nickel reference dose does not mean that an adverse health effect will occur, it does trigger or point to the need for further investigation.

As a result of the findings for the single Rodney Street property, the Medical Officer of Health requested additional sampling of residential properties on Rodney Street. This additional sampling of front and back yards was completed October 3 and 4, 2000. A preliminary analysis of the results showed a wide variance in soil nickel concentrations from one property to the next, and in some cases between yards on the same property. The highest soil nickel concentration was 17,000 µg/g, but several samples were substantially above the 2,000 µg/g to 4,000 µg/g nickel range that was anticipated for this area of Port Colborne, based on the Ministry's 1998 and 1999 studies (Kuja et al., 2000a; Kuja et al., 2000b). On some properties the nickel concentrations were highest in the surface soil and lower at depth, while on other properties the reverse was observed. Properties with higher soil metal levels were sometimes adjacent to properties with much lower metal concentrations. Soil nickel concentrations tended to be higher in the front yards of Rodney Street properties than the back yards. This may reflect re-entrainment of contaminated dust along the roads or snow plowing and piling of dust-contaminated snow. In addition to unexpectedly high nickel, copper, and cobalt levels, the soil zinc, arsenic, and in some cases lead concentrations, were also elevated on some properties and were inconsistent with levels previously observed elsewhere in the Port Colborne area. While collecting soil from the Rodney Street properties it was observed that some areas of some yards had considerable non-soil material, such as concrete rubble and metal pieces, and what appeared to be cinders, slag, and possibly ash. This suggested that some areas of what is now Rodney Street may have historically received fill, possibly residential refuse or industrial process waste.

In an open letter to the residents of Port Colborne (December, 2000) concerning nickel, copper and cobalt in surface soil in and around Port Colborne, Inco stated that "Inco no longer refines nickel in Port Colborne, but we do acknowledge these metal levels are the result of Inco's historic operations in Port Colborne." (Inco, 2000).

The sources of the soil metal contamination found on some Rodney Street properties could be both stack and fugitive emissions from the Inco refinery, or historic emissions and/or disposal of process waste from Inco or other past local industries. Due to its close proximity to the refinery, the Rodney Street community was almost certainly subjected to extensive fugitive emissions, which would have been particularly significant early in Inco's operating history. Fugitive emissions are process emissions that "leak" out of windows, doors, vents, other openings, or are transported from on-site contaminated land to off-site areas by vehicle traffic. In the Ministry's experience, fugitive emissions are more likely to impact areas closest to the manufacturing site and may result in very high levels of deposition, although fugitive emissions tend to fall off relatively quickly with increasing distance from the source. Fugitive emissions may also result in localized or somewhat patchy areas of contamination, as they may originate from very specific areas of the source (single doors or vents, or specific ingress/egress roads). In contrast, stack emissions can have an impact over a much greater area, deposition tends to concentrate in the predominant downwind direction, and contaminant levels tend to fall off gradually over considerable distances.

Other than Inco, the only other known significant historic industry that had the potential to substantially impact soil quality in the Rodney Street community was the Algoma Steel/Canada Furnace (Algoma) blast furnace and steel mill that operated from 1913 to 1977. The iron ore blast furnace operated by Algoma was about as far away from the Rodney Street community to the west-southwest as Inco is to the east-southeast. Emissions from Algoma may have included arsenic, iron, magnesium, possibly beryllium, boron, manganese, calcium, phosphorous, sulphur, silicon, plus substantial particulates (dust).

In addition to industrial waste, the soil contamination along Rodney Street could be related to contaminated fill that may have been brought into the area during sewer or water line construction, or from an oil pipeline that was constructed in about 1957 and runs from the Welland Canal along the centre of Rodney Street, up Davis Street, and into the Inco refinery. The long time use of leaded gasoline, improper disposal of batteries, the weathering or removal of lead-based paint from exterior walls of residential dwellings, and the use of lead-based pesticide may have contributed to the elevated soil lead concentrations on some properties.

The extent of the unexpectedly high soil metal levels encountered on Rodney Street in October 2000 was anticipated to be quite limited (isolated pockets) if the source was contaminated fill. If contamination was more widespread (ie., properties beyond Rodney Street) as a result of fugitive or stack emissions from local industry, soil concentrations would be expected to be very high over the general area and decrease with increasing distance from the source. The preliminary Rodney Street data introduced new environmental information, in that the nickel levels were higher and additional contaminants (ie., lead and arsenic) were encountered. Although Inco was the known source of nickel in the broader Port Colborne area, Inco may not be the source of these other contaminants. In addition, the variability of the soil metal levels between properties made it difficult to judge the extent of the contamination. Therefore, in order to determine with certainty if the elevated soil metal concentrations are due to contaminated fill and limited only to Rodney Street, all residential properties in the Rodney Street community immediately west of the Inco refinery (south side of Louis Street to Rodney Street, from Welland Street east to Inco) were sampled by Ministry scientists from November 8 to 17, 2000. In addition to the residential property sampling, soil trenches were dug at several locations in the vicinity of Rodney Street to determine if soil was contaminated at depth. Also, the City of Port Colborne requested that the MOE sample the playground located on the east side of Welland Street north of Nickel Street, as fill had been used in the construction of the berms in this park.

After the April, 2001 open house meeting hosted by the Ministry in Port Colborne, several property owners notified the Ministry that their properties, or areas on their properties, had not been sampled in the Rodney Street community-wide sampling program of November 2000. Between April and July, 2001, Ministry scientists sampled surface soil from additional residential properties. These additional properties were not sampled the previous November because access was unobtainable after repeated attempts, or they were vacant lots with obvious signs of very recent disturbance, or there was confusion about property boundaries. In at least one case, the property had been sampled in November 2000 but the owner asked that a specific section of the yard be sampled be sampled in 2001 that had not been previously sampled.

## 4.0 MOE Soil Guidelines

Interpretation of soil metal levels in this report is based on comparisons to the MOE *Guidelines for Use at Contaminated Sites in Ontario* (MOE,1997). In 1996 the Ministry published the soil guidelines (revised in 1997) to help owners of contaminated industrial property clean up the soil so that the property could be redeveloped for alternative uses. Although the soil guidelines were developed specifically for remediating single contaminated industrial properties, they have been used by both the Ministry and the environmental consulting community to evaluate soil quality on a broader scale.

The use of the Ministry's soil clean-up guidelines are voluntary, although the Ministry can order property owners to follow them in order to remediate contaminated soil if the contamination has the potential to cause an off-property adverse effect or can order the polluter to remediate if the contamination itself constitutes an off-property adverse effect. A discussion regarding the approaches available can be found in Appendix 1.

The Ministry's soil clean up guidelines, including the SSRA approach, have been used successfully on hundreds of properties across Ontario to restore the economic and social value of previously contaminated lands.

The Table F guidelines represent background soil concentrations obtained from a MOE province-wide parkland sampling program. Soil concentrations that exceed Table F are usually indicative of a pollution source. The Table A soil guidelines are effects-based and were derived to protect both human health and the natural environment, whichever is potentially affected at the lowest concentration. Table A guidelines are not available for all chemical parameters, since for some elements there is insufficient scientific information available to establish effects-based values (ie., strontium), or the element is considered non-toxic even at high concentrations (ie., iron), or the element is a plant nutrient (ie., magnesium).

An exceedence of a Table A guideline does not mean that an adverse effect will occur, it means that an effect may occur if the specific sensitive environmental receptor the guideline is intended to protect is present at the site and the soil conditions are such that the contaminant is readily bio-available (see Part A Section 5.3.3 for an explanation of bio-availability as it relates to ecological toxicity; Part B Appendix 5 explains bioaccessibility as it relates to human toxicology). For example, the nickel Table A guideline of 200 µg/g is intended to protect sensitive agricultural crops, specifically cereal grains such as oats, because these plants are injured at soil nickel levels far below most other plant species. In addition, even sensitive cereal crops will not be injured at 200 µg/g nickel unless the nickel in the soil is readily bio-available. Usually bio-availability of metals increases as: metal concentration increases; the concentration of soluble forms of the metal increase; soil pH decreases; soil cation exchange capacity decreases; soil nutrient levels decrease; soil organic matter decreases; and, soil clay content decreases/soil sand content increases.

The Ministry's generic soil nickel guideline of 200 µg/g is based on eco-toxicity (injury to plants), because plants are the most sensitive environmental receptor. The Ministry does not have a generic (Table A) soil nickel guideline based on human health. However, when a proponent uses the SSRA approach to remediate a property, the Ministry has a value of 310 µg/g nickel in soil that triggers the need to conduct a human health risk assessment (MOE,1996). For example, if the soil nickel level is higher than 200 µg/g (the generic Table A guideline) but does not exceed 310 µg/g, the SSRA need only include an ecological risk assessment. If the soil nickel level is greater than 310 µg/g, the SSRA must include both an ecological risk assessment and a human health risk assessment. The 310 µg/g human health component value is neither a standard nor a guideline, it is only used as a screening level that triggers the requirement to conduct a human health risk assessment.

Regardless of the sensitivity of the soil and the presence of sensitive environmental parameters, the MOE generic soil guidelines are not used at all if a site specific risk assessment is used to evaluate the potential impact of the soil contamination and derive remedial options. The human health risk assessment described in Part B of this report is part of a site specific risk assessment, and therefore the MOE generic soil guidelines do not apply to the Rodney Street community. However, the soil guidelines are referenced to allow comparison to background levels and evaluate the potential for adverse ecological and human health effects.

## 5.0 Methods

### 5.1 Soil Sampling

The details of sampling dates are presented in Section 3.

Initial sampling on 17 properties on Rodney Street was conducted to a depth of 15 cm. Since the results of this sampling showed metal levels were still significantly elevated at 15 cm, the sampling depth was increased to 20 cm for subsequent sampling. Efforts were made to sample all yards on all properties in the Rodney Street community, but in some cases conditions made it impossible to collect an appropriate soil sample. Sampling to the 20 cm depth was not possible on every property, as occasionally stony fill was encountered. Also, some yards were covered with gravel, asphalt, or debris (ie., car parts, construction material), which physically prevented the investigators from sampling soil. Soil samples were not collected within one metre of driveways, walkways, building structures, fences and debris, to reduce the likelihood of encountering local residential sources of contamination (ie., driveway spills, paint chips). This one metre "buffer" area disqualified some small yards/areas on some properties during the November 2000 sampling. At the property owner's/occupant's specific request, some of these small areas were sampled in April and May 2001.

For each yard on a property, a manually operated soil corer was utilized to collect a minimum of nine soil cores, while walking a grid, "W"or "X" pattern across the designated sampling area. This meant that soil cores were collected from at least nine discrete areas of each yard sampled. Each soil core was divided into three depth intervals (0-5 cm, 5-10 cm, and 10-20 cm) and the core sections (ie., 0-5 cm) were placed in one labelled polyethylene bag for each of the three sample depths. The nine core sections per bag are referred to as a composite soil sample.

Where only one yard was sampled using the composite single sample procedure, and soil could be obtained from all three depths, then soil would actually have been collected from a total of 27 soil core sections per yard (1 yard X 9 cores X 3 depths = 27 soil cores sections). Duplicate sampling means the soil sampling procedure was repeated over the same sampling pattern per yard. A yard sampled in duplicate for which soil could be obtained from all three depths would actually have had soil collected from a total of 54 soil core sections (1 yard X 9 cores X 2 replicates X 3 depths = 54 soil core sections). Triplicate sampling means the soil sampling procedure was repeated three times over the same sampling pattern per yard. A yard sampled in triplicate for which soil could be obtained from all three depths would actually have had soil collected from a total of 81 soil core sections (1 yard X 9 cores X 3 replicates X 3 depths = 81 soil core sections). Table 5-1 indicates how many soil core sections were obtained on a property if soil was obtained from all three depths and multiple yards on a property were sampled using single composite, duplicate, or triplicate sampling procedures. Assuming soil could be obtained from all three depths, the minimum number of soil core sections sampled per property ranged from 27, representing 3 composite samples if only one yard was sampled, to as many as 243, representing 27 composite samples, if three yards were sampled in triplicate at all three depths.

The yards of all of the properties on Rodney Street sampled in October 2000 were sampled in duplicate. Of the properties in the Rodney Street community sampled in November 2000, most were sampled using single composites, while 10 percent of the properties were sampled using triplicate composites (typically two properties in each block). Properties in the Rodney Street community sampled in April and July, 2001 were composite sampled in duplicate. Duplicate and triplicate sampling was done to provide a measure of the sampling variability. This is described in detail in Section 5.3.6.

## 5.2 Trench Sampling

Seven trenches, 2 metres long by 0.5 metre wide, were dug using a backhoe supplied by the City of Port Colborne. The purpose of the trenches was to obtain soil samples at depth to estimate how deep the contamination extended, and to observe the soil profile for signs of fill, refuse, or industrial process waste. Trenches were excavated to a depth at which contact was made with natural clay, which was about one metre in most trenches. Duplicate soil samples were removed from the sides of each trench using a trowel at three depths: 30-35 cm, 60-65 cm (which were within what appeared to be layers of coarse fill material), and 100-105 cm. Soil samples were placed in labelled, polyethylene bags.

The seven trenches were excavated from four areas: 1) Two trenches were excavated in the baseball diamond at the southwest corner of Davis Street and Rodney Street. One trench was located on the outfield side of second base and the second trench was dug in the middle of the outfield. 2) Two trenches were excavated in the vacant lot situated on the south side of Rodney Street between Welland and Fares Streets. This lot was owned by Algoma from 1920 to 1992 and is currently owned by Inco. One trench was about ten metres in from the southeast corner of Welland and Rodney Streets, and the second trench was about ten metres in from the southwest corner of Fares and Rodney Streets. 3) One trench was excavated directly in front of the residence at 124 Rodney Street on the north shoulder of the road. 4) Two trenches were excavated on the west side of the playground located between Welland Street and Fares Street, north of Nickel Street. In addition, 0-5 cm, 5-10 cm, and 10-15 cm duplicate soil samples were collected from eight sites along a sod-covered berm running around the north and west perimeter of the basketball court located in the same playground.

## 5.3 Soil Sample Preparation and Analyses

### 5.3.1 Metals and Hydrides

All soil samples were stored in locked vehicles while not in view of the investigators until they were delivered to the Ministry's Ecological Standards and Toxicology Section for processing using standard MOE chain of custody and laboratory procedures (McIlveen and McLaughlin, 1993). The samples were air dried and passed through a 2 mm sieve where vegetation and stony debris were removed, and then ground to pass through a 355 micron sieve. The fine soil fraction was transferred to the MOE Laboratory Services Branch (LSB). Because of the need to have the analyses conducted as quickly as possible, LSB arranged to have the Rodney Street community soil samples analysed by an accredited private environmental laboratory. LSB imposed a strict quality management regime on the private lab to ensure data integrity (refer to Section 5.3.5). The soil samples were analysed for the following metals: aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, strontium, vanadium, and zinc. For these metals, samples analysed by LSB used the accredited analytical method E3073L1. In addition, the hydrides arsenic, antimony, and selenium were also included in the soil analysis. For the hydrides, samples analysed by LSB used the accredited analytical method E3245L1. Unless otherwise specifically identified, all the soil data in this report are reported as dry weight totals.

### 5.3.2 Determination of Soil pH

To assist in the interpretation of the bio-availability of the soil contaminant concentrations, soil pH was determined for a subset of 36 soil samples collected from across the ten blocks of the Rodney Street community. Soil pH was determined in distilled water using MOE standard procedures (MOE,1985).

### 5.3.3 Soil Bio-availability

Between 1969 and 1979, the Ministry conducted several investigations and prepared many reports on soil and vegetation chemistry in the Port Colborne area. During this time, soil was collected from urban and rural properties (typically mineral soil) and selected farm fields (typically organic "muck" soil) to determine nickel bio-availability using a weak ammonium acetate extraction. Ammonium acetate extraction was not done on samples collected in 2000 or 2001.

The bio-availability data in Part A of this report relate to soil conditions that affect the natural ecosystem, specifically vegetation. The ammonium acetate extraction used on soil is intended to simulate the leaching of metals from the soil by natural rainfall, soil water movement, and normal soil microbial activities. The extraction process used to estimate the leaching of soil metals into the human gastrointestinal tract to evaluate the potential impact on human health from the ingestion of contaminated soil is an entirely different test and is covered in this report in Appendix 5 of Part B Human Health Risk Assessment.

### 5.3.4 Nickel Speciation

Nickel can occur in various forms in the environment and as a result of industrial processes. Examples of forms of nickel are nickel oxide, nickel subsulphide and nickel chloride. These forms are referred to as nickel species. The species of nickel in the soil can have an important impact on its availability and its toxicity for both the natural ecosystem and human health. However metal speciation in soil samples is non-routine, and few labs can provide quantitative results. Nickel speciation was conducted on selected samples. The Ministry shared processed soil composite samples from properties on Rodney Street with Inco and both organizations had qualitative tests conducted at different laboratories; Inco used their own research facility and the MOE used the Ministry of Northern Development and Mines Geoscience Laboratory in Sudbury. In addition, the Ministry submitted selected soil composite samples for quantitative analysis to Lakefield Research in Ontario and to the Stanford Synchrotron Radiation Laboratory in California.

### 5.3.5 Data Management and Laboratory Quality Control

In order to expedite the analysis of the more than 1,500 soil samples collected from the Rodney Street community, the MOE retained the services of Agat Laboratories, an accredited private laboratory. Agat analysed the samples collected from the Rodney Street community in November 2000. The MOE Laboratory Services Branch analysed the samples collected from the Rodney Street properties in October 2000, and the additional properties in the Rodney Street community collected from April to July, 2001. The management of the contract lab was carried out by senior scientists and managers of the MOE Laboratory Services Branch (LSB). The contract with Agat Laboratories was signed only after a thorough review of their proposal and laboratory procedures and a successful analysis of preselected test samples. The MOE analysed the first 100 soil composite samples from the November 2001 sampling of the Rodney Street community. These same 100 samples were then analysed by Agat Laboratories by ICP-MS and the results compared. This initial comparison was done by staff of the MOE LSB Quality Management Unit. The acceptance criterion was 20%, which is the criterion used for routine MOE in-house quality control duplicate samples. In other words, all of the Agat Laboratory individual element results had to be within 20% of the corresponding MOE results for the same sample. Only after this first quality assurance target was met successfully were the remaining Rodney Street community samples sent to Agat Laboratories. This potential difference in ± 20% is the analytical component of the combined sampling and analytical "error" described in Section 5.3.6 Soil Sampling

Strategy.

All sample submissions sent to Agat Laboratories contained at least four "check" samples which had been previously analysed as part of the original 100 samples. Each submission also contained field replicate samples, which could be used to measure repeatability of the sampling and analytical processes. The preliminary acceptance criteria were 20% for the check samples and 50% for the field replicates. The field replicates had a higher acceptance bracket because it was known from previous work in Port Colborne that between-replicate variability increased as the soil contaminant concentration increased. This is a common occurrence for non-homogeneous samples. Data checking was performed by the manager and a senior scientist of the MOE LSB Spectroscopy Section, as well as Phytotoxicology scientists.

Data was quality assured in several ways. If the results for the "check" samples and the replicate data were acceptable, then the rest of the data were checked for outliers. Outliers were determined by reviewing the ratios of elements between samples in each laboratory submission. Several sample submissions were repeated because the ratios of certain elements did not match the observed general trend. In almost all cases, repeat analysis by Agat Laboratories, and in some cases by MOE, confirmed the original result. Repeat analysis was continued until the data either matched the original "check" samples or were confirmed by MOE analysis. Generally, outliers were found to be due to the improper use of dilution factors. Outlier sample results were either re-calculated or Agat Laboratories was required to repeat the analyses. The variability in field replicates that was finally reported was much less than the 50% used as an acceptance criteria (refer to Section 7.1). Once all these criteria were met, the data were released to the principal authors for use in the preparation of this report.

### 5.3.6 Sample Variability, Data Confidence, and the Application of the Soil Nickel Intervention Level

Section 5.1 discussed the strategy used to sample the properties in the Rodney Street community. The sample strategy used in the Rodney Street community was appropriate for its intended purpose, which was to collect information on soil contaminant levels that reflect representative environmental exposures to people using the property. All sampling strategies, no matter how thorough, have inherent variability because they can only estimate, not measure, the soil chemical concentrations. The term used to identify this inherent variability is "sampling error". It is a statistical term used to identify uncertainty, it does not imply the data are wrong.

In consideration of the variability inherent in sampling soil and laboratory testing, the Ministry used the maximum nickel concentration found in any soil composite sample at any depth in the front, back or side yard, to determine if a property exceeded the soil intervention level derived from the human health risk assessment. If the maximum concentration exceeded the intervention level, the property becomes a candidate for soil remediation. Even though the maximum concentration is a worst case estimate of the overall property concentration, because of soil variability a property owner/occupant could still have concerns that the maximum nickel concentration found on the property is an underestimate of the true (but unknown) nickel concentration. By determining the variability around the maximum measured concentration a confidence interval for any specific concentration can be calculated.

The soil data from the properties were statistically evaluated to determine the confidence interval around the maximum value of all the samples collected from any single property. Given the large data base and the log-normal distribution of the soil nickel levels across the Rodney Street community, the asymptotic distribution (also known as the Gumbel distribution - see Johnson and Kotz, 1995) of the maximum likelihood estimates (normal) was used to construct confidence intervals around the maximum concentration for any property. From the Human Health Risk Assessment it was determined that at a soil nickel concentration of 9,061 µg/g (refer to Part B Section 7.1) the nickel exposures from all sources, including the Rodney Street community soil-specific exposure, is less than the RfD for all age groups including the toddler. Using the confidence intervals from the Gumbel distribution of the combined 2000 and 2001 Rodney Street residential soil data, it can be shown that, if the maximum soil nickel level of any single sample at any depth from a property is 8,139 µg/g or less, it is 99% certain that no sample on the property would exceed 9,061 µg/g. Based on these calculations the soil intervention level is proposed at 8,000 µg/g nickel.

## 6.0 Results

### 6.1 Nickel Speciation

### 6.1.1 Qualified Nickel Speciation Results and Mineralogy

In previous MOE reports pertaining to soil contamination in Port Colborne, the metal concentrations have been reported as the "total" (refer to Section 5.3.1) amount of nickel in the soil. Prior to 2000, the MOE soil studies in Port Colborne did not speciate the various metal compounds in local soil. The main issue arising from the health related concerns expressed by the community was the species of nickel present in Rodney Street community soils. Of particular concern were the relative amounts of nickel oxide in the soil, as nickel oxide is a component of nickel refinery dust. Nickel refinery dust is a mixture of nickel compounds that is a potential lung carcinogen if inhaled.

Speciation of nickel in soil is both a time consuming and non-routine process because it requires specialized laboratory equipment and specially trained equipment operators/scientists. For these reasons metal speciation is not routinely conducted in environmental investigations, and was not previously done on Port Colborne soil samples.

Nickel speciation was conducted on selected soil samples collected from properties on Rodney Street (not the Rodney Street community, but just properties on Rodney Street) independently by both the Ministry of Northern Development and Mines (MNDM) Geoscience Laboratory in Sudbury (MNDM, 2001) and by Inco (Inco, 2001a). Jacques Whitford Environmental Ltd.

(JWEL) also submitted selected soil samples from across Port Colborne for metal speciation as part of their sampling program to determine the contaminants of concern for the Community Based Risk Assessment currently underway in Port Colborne (Enpar, 2001).

The MNDM report concluded that nickel oxide was detected in the magnetic fraction of each sample, and that no other nickel form or species was detected in either the magnetic or non-magnetic fractions of any of the samples. The Inco report had similar conclusions: the only forms of nickel identified in soil samples collected from Rodney Street were elemental nickel, nickel alloys (ie., nickel-copper alloy), and nickel oxide, but specifically neither sulphidic nor halide forms of nickel were detected. The results from the more recent work conducted by JWEL concurred with both the MNDM and Inco reports, in that nickel oxide was the only nickel compound detected, with no evidence of either sulphate or sulphide nickel forms.

Some of the Rodney Street property soil samples examined for nickel speciation by MNDM and Inco were very heterogeneous, containing up to 30 - 40% non-soil (artificial/man-made) material. The most abundant man-made phase was iron oxide, but included metallic iron, carbonaceous particles that could be coke or coal dust (probably coke because of the presence of gas-bubbles), the occasional arsenic grain hosted in iron oxide and associated with copper, nickel, antimony, and molybdenum. The iron oxide was often in the form of dendritic iron oxide crystals, suggesting an artificial origin. Precious metal inclusions with platinum and palladium were identified in several particles in one sample, which were alloyed with copper and hosted in nickel oxide (Inco, 2001a).

This material was obviously artificial in origin and the presence of nickel, copper, cobalt, and precious metals suggests an Inco origin. However, the presence of quantities of manganese slag with high silicate and iron concentrations in some samples is more typical of blast furnace slag, and suggests some of the iron-based material found in soil from Rodney Street properties may have originated from Algoma.

The following material is drawn from information Inco provided to MOE about past refinery processes and wastes for the early years of the Port Colborne refinery's operation. Orford slag is a particular slag produced by the Orford process, which was used at the Inco Port Colborne refinery from 1918 to the mid 1930s. If some of the soil contamination found on the Rodney Street properties was associated with slag waste from Inco's early operations then the soil chemical and mineralogy characteristics may be similar to Orford slag. If the soil chemical structure is considerably different from Orford slag then the source of the soil contamination may be other Inco processes, or later emissions from Inco, or another local industrial source, such as slag waste from Algoma. A single Orford slag sample was examined by Inco from their on-site Orford slag pile and the results made available to the Ministry (Inco, 2001b). This Orford slag sample had soda, sulphur, cobalt, and copper levels that are about ten times higher than the average of the Rodney Street soil samples examined by Inco and the Ministry. The Rodney Street soil iron levels are comparable to the slag sample and the soil nickel levels are about twice as high as in the slag sample. In addition, the nickel and copper bearing phases present in the Orford slag are mostly sulfides, which is in contrast to the Rodney Street soil samples in which nickel oxide is the most common nickel form. As process changed at Inco, slags with different metal compositions, including nickel oxide, were likely produced.

A direct comparison of the chemical and mineralogy characteristics of a single slag sample and the results from several soil samples is not decisive. Slag, or other waste, deposited in the vicinity of properties on Rodney Street would be mixed with soil and influenced by natural microbial processes and residential activities that are not active in the slag pile. The dilution associated with soil mixing could account for some of the differences in metal concentrations, and deposition of nickel particulates associated with stack and fugitive emissions could enrich the soil nickel levels.

Over time, and in a dynamic soil environment, the sulphidic forms of nickel in Orford slag could be leached away or altered to other nickel species and the most insoluble nickel forms (nickel oxide) would remain in the soil. The Orford slag is not the only slag, nor the only waste generated by Inco. The presence of silica and iron enriched manganese slag, may suggest that slag from Algoma has contributed to the soil contamination on some of the Rodney Street properties and possibly the area south of Rodney Street. However, elevated nickel, copper and cobalt concentrations are not known to be associated with iron foundry slag. In contrast, the presence of very elevated concentrations of nickel, copper are associated with Inco.

### 6.1.2 Quantified Nickel Speciation Results

The original Rodney Street soil samples examined for nickel speciation for the Ministry by MNDM and by Inco both confirmed the presence of nickel oxide but no other nickel species. These analyses could not quantify the concentration of nickel oxide. Therefore, the Ministry contracted two additional laboratories to conduct further nickel speciation testing in an attempt to quantify the various nickel forms in the soil. Quantification of metal speciation in soil samples is non-routine, leading edge science. The Ministry sent 20 soil samples from the broader Rodney Street community to Lakefield Research in Ontario and six samples to the Stanford Synchrotron Radiation Laboratory in California. The results of these analyses are summarized in Table 6-1.

Lakefield Research methodology used a sequential leaching process to isolate and then quantify the various metal species groups. The Stanford lab methodology used SEM-XAFS (scanning electron microscope - X-ray absorption fine structure). The 20 samples sent to Lakefield consisted of composite samples collected from ten sites. Ten samples were collected and split into two portions. One half (ten) was processed following the standard MOE sample preparation protocol (grinding and sieving), and the other half were submitted as unprocessed bulk samples. This was done to evaluate the effect of sample processing on the results. Portions of the same ten samples (also ten processed and ten unprocessed) were sent to another outside lab for simulated stomach acid leach analysis (see Part B Human Health Risk Assessment, Appendix 5). Three replicates each of two processed samples (six samples in total) were sent to the Stanford lab. The

Ministry's Laboratory Services Branch conducted analysis of total nickel on the ten processed samples.

Both labs were able to provide quantitative estimates of speciated nickel. Lakefield methodology identified four fractions of nickel in the processed and unprocessed samples; soluble nickel, nickel sulfide, nickel metal, and nickel oxide. The processing status made no appreciable difference in the results. On average, nickel oxide comprised just over 80% (range from 54.6% to 87.7%) of the total nickel in the Rodney Street soil samples analysed by Lakefield. Lakefield found nickel metal present at 11.3%, nickel sulphide at 7.66%, and soluble nickel at 0.37% of the total nickel detected in the processed soil. By comparison, the six samples analysed by the Stanford lab averaged 89.5% nickel oxide, but this lab did not observe any other nickel species. Inco's ongoing analytical work in Port Colborne indicates that the majority of the nickel present in soil in the Rodney Street community is in the form of nickel oxide with traces of nickel metal and nickel:copper and nickel:cobalt alloys. However, Inco has not identified nickel sulphide or other nickel species in any of the Rodney Street soil samples it has examined.

The analytical procedures employed by the Lakefield and Stanford labs are very different, and at this time there is not a weight of evidence to suggest that one process is more accurate than the other. In this case there are three labs (Inco, Enpar, and Stanford), all using Scanning Electron Microscopy technology, that detected only nickel oxide, and one lab (Lakefield) that detected traces of other nickel species in addition to nickel oxide. All labs concur that nickel oxide is the most abundant nickel species present in the soil. Therefore, the conclusions to be drawn from the new nickel speciation tests reaffirm the position originally stated by the Ministry that the majority of the nickel in the soil in the Rodney Street community is in the form of nickel oxide. Considering the uncertainty associated, at this time, with this leading edge analytical technology, the presence of nickel species other than nickel oxide in trace concentrations in soil in Port Colborne is speculative until it can be confirmed with repeat analysis of samples from multiple locations using different laboratories.

Table 6-2 summarizes data from a 1978 report of analyses of Port Colborne refinery dusts (MOE, 1978a). This report provides elemental analysis of a dust sample collected from the Cottrell Precipitator, the Cobalt Multiclone Stack, the Tumblast Stack, and the Submerged Combustion Evaporator Stack. The data from an onsite "Cottrell" Precipitator captured dust from the Anode Reverb Furnaces during charging, smelting, and on-stream periods of operation, and so should reflect the particulates present in stack and fugitive emissions in the 1970s. The precipitator dust was 38.7% nickel, 10.5% lead, 7.6% copper, 7.1% sulphur, 0.66% cobalt, 0.61% iron, 0.38% arsenic, and 0.14% zinc. The main nickel component was reported as nickel oxide and the main lead component was reported as lead sulphate. In addition, "minor phases" (not quantified) of hydrated nickel and copper sulphate were identified. Therefore, most of the nickel in precipitator dust, and so likely in the stack and fugitive emissions in the 1970s, was nickel oxide.

It is important to note that the MOE Table A effects-based guideline for nickel was developed for the total nickel concentration in the soil and is not based on nickel oxide; ie., it is a nickel guideline, not a nickel oxide guideline.

## 6.2 Soil Results
### 6.2.1 Data Tables

The test results for all soil samples taken from residential properties in the Rodney Street community in 2000 and recent data from 2001 are summarized in Tables 6-3 (2000) and 6-4 (2001). Table 6-5 summarizes the test results of the trench samples collected in 2000. In addition, the 2000 residential soil data are summarized in four tables that list the minimum, maximum, mean, and median datum plus the 10th to the 90th percentiles. Table 6-6 summarizes the 0-5 cm sampling depth from all residential properties sampled in 2000, Table 6-7 summarizes the 5-10 cm depth data, Table 6-8 summarizes the 10-20 cm depth data, and Table 6-9 summarizes the soil data by all depths combined. The 2001 residential data is not included in the statistical summary tables or in the concentration contour maps. The 2001 results are consistent with the 2000 residential data, in that no new contaminants were identified and the concentrations were comparable. Because the 2001 data set is small (about 5% of the samples collected from the Rodney Street community) and the levels are similar, their exclusion has no significant impact on the overall conclusions of this report.

The distribution of nickel in soil in the Rodney Street community is very skewed. The 90th percentile of soil nickel concentrations (all depths combined) for all samples collected in 2000 is 5,588 µg/g, which means only 10% of all the samples exceed the value of 5,588 µg/g. The 50th percentile was 1,800 µg/g, which means that half of all samples tested are less than 1,800 µg/g. Also, 80% of the samples were less than 3,900 µg/g, which is consistent with the data in the 1998 and 1999 Port Colborne MOE soil investigations that predicted that soil nickel levels in this community are in the range of 2,000 µg/g to 4,000 µg/g.

### 6.2.2 Soil pH

Soil pH results for the 36 soil samples containing high soil nickel concentrations are listed in Table 6-10. The pH of soil in the Rodney Street community ranged from 6.85 to 7.76, which is characteristic of neutral, fine-textured mineral soil and common in surface soil in southern Ontario. The soil pH was determined on soil samples collected form the 0 to 5 cm sample depth.

### 6.2.3 Soil Plant Bio-availability

The soil plant bio-availability of nickel in pH-neutral mineral soil averaged 0.22%, whereas the bio-availability in acidic organic (muck) soil averaged 8.49% (MOE,1975; MOE,1977; MOE,1978). None of the samples analysed for plant bio-availability were collected from sites where slag or other process waste was observed and all sites were believed to have been contaminated through atmospheric deposition. The nickel bio-availability was much higher in the muck soil, because these farms were directly downwind of Inco where soil nickel levels tend to be higher (greater than 5,000 µg/g), than the mineral soils that are more common elsewhere in Port Colborne. Also the muck soils are naturally more acidic, which would place more nickel in soil water solution, available to plants.

These results indicate that the potential for nickel to go into solution in the soil and be available for uptake by vegetation (plant bio-availability) is very small for the type of mineral soil that predominates in the Port Colborne community. This would explain the paucity of characteristic vegetation nickel injury symptoms on plants throughout Port Colborne, even though soil nickel levels far exceed the Ministry's effects-based Table A nickel soil guideline. After the shutdown of the refinery in 1984, nickel injury on sensitive species of vegetation has rarely been observed in Port Colborne. This corroborates the low soil nickel plant bio-availability results and suggests that most of the nickel injury observed on vegetation up to 1984 was likely from deposition of nickel from the ambient air onto plant surfaces and absorption, and not from translocation of soluble nickel from nickel-contaminated soil. No plant injury believed to be caused by nickel toxicity was observed in the Rodney Street community during the course of sampling in 2000 and 2001.

The low plant bio-availability of nickel in soil is associated with a neutral soil pH, and a very low ammonium acetate soil leach is consistent with nickel being in the form of the very insoluble nickel oxide or nickel metal. Very low plant bio-availability would also explain the rarity of nickel injury symptoms on vegetation in the Rodney Street community specifically and the Port Colborne area in general. In order for nickel in the soil to injure vegetation it must be dissolved in soil water, taken up through the roots, and translocated throughout the plant. With such low bio-availability there would be very little dissolved nickel in soil water resulting in a small potential for vegetation uptake and injury.

The low soil plant bio-availability would also explain the generally poor relationship between soil nickel levels and nickel levels in residential garden produce observed in Port Colborne (ie., the nickel levels in garden produce were not consistently higher from properties that had high soil nickel concentrations). In fact, a linear relationship between plant nickel levels and soil nickel levels would not be expected, as nickel is toxic to plants and plants would not grow as well in highly nickel contaminated soil. Preliminary data from the eco-toxicity testing being conducted for the CBRA has confirmed that plant growth is substantially reduced at high nickel levels.

## 7.0 Discussion

### 7.1 Soil Results for Residential Properties

MOE Table A effects-based generic criteria (residential/parkland land uses - medium/fine textured soils) were exceeded in soil on one or more of the residential properties in the Rodney Street community for the following ten elements: antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, nickel, selenium and zinc. The Table A Guideline (refer to Section 4.0 and Appendix 1) for lead, antimony, and beryllium are based on human health. These are intended for generic clean-up or as a trigger for a detailed HHRA. The criterion for selenium is based on the protection of grazing animals. The criteria for arsenic, cadmium, cobalt, copper, nickel, and zinc are based on ecological protection, specifically plant growth. Soil nickel concentrations exceed the Table A effects-based generic criterion of 200 µg/g on almost all of the properties in the Rodney Street community. It was evident from the condition of the few properties that did not exceed the nickel guideline that they had undergone extensive landscaping, so the contaminated soil had either been buried below the 20 cm sampling depth, or been removed and replaced with clean soil.

Elevated soil nickel levels were expected in the Rodney Street community, since the contaminant contour maps prepared for the 1998 and 1999 MOE Port Colborne soil investigations indicated that soil nickel concentrations in the area could range up to 5,000 µg/g. Similarly, soil cobalt and copper concentrations were expected to be high, and about 61% and 54% of the properties, respectively, in the Rodney Street community exceeded the Table A effects-based criteria for these two elements. A high percentage (approximately 80%) of the properties sampled in this investigation also had soil lead levels above the Table A effects-based criterion. Soil beryllium levels on almost one half (49%) of the properties exceeded the Table A effects-based criterion. The effects-based criteria for arsenic and zinc were exceeded on about one quarter of the properties (29% and 17%, respectively). Table A guideline exceedences were rare for antimony, cadmium, and selenium, occurring on only three properties (2%) for antimony, and one property each (1%) for cadmium and selenium.

Statistical analysis was carried out on the replicated samples collected from the two properties on each block that were sampled in triplicate (single samples were collected from all other properties in the Rodney Street community and the properties on Rodney Street were sampled in duplicate). Within site sampling/analytical variability was acceptable for most elements (excluding antimony and selenium), in that the standard deviation of the replicates was less than 20% of the mean value for the property. The standard deviations of the replicate samples for antimony and selenium, expressed as percentages of the mean concentration, were 24.2% and 24.6%, respectively. The concentrations of both antimony and selenium are naturally very low in soil, usually less than 0.2 µg/g. The high variability between sample replicates for these two elements was related to the difficulty that the contract laboratory had in consistently obtaining detection limits that were in the 0.2 µg/g range. A low detection limit for these elements was not a selection criteria for the contract lab, since high metal levels were anticipated.

## 7.2 Contaminant Contour Maps

### 7.2.1 Map Preparations and Precautions

To illustrate the spatial distribution of soil contamination in the Rodney Street community, contaminant contour maps were created for selected elements using Surfer™ and ArcView™ computer mapping programmes. Because of the technical complexities associated with creating contour maps from a very large data base, and because no spatial pattern was evident for some elements, maps were created only for the elements of specific interest and those that exceeded the

MOE Table A effects-based guidelines for which the guideline rationale was health-based. Zinc was excluded, because with few exceptions, the exceedences of the Table A effects-based criteria were marginal, and the rationale for the guideline is not health-based. Iron was included because it is a potential emission from both Inco and Algoma, and even though environmentally it is a (relatively) benign contaminant, a spatial pattern may assist in contaminant source allocation. Therefore, maps were prepared for the following ten elements: antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, nickel, selenium, and iron. A separate contaminant contour map was produced for each of the three sampling depths (0-5 cm, 5-10 cm, and 10-20 cm) for each element.

Two software packages were used to generate the maps. The data analysis and creation of the concentration contours were produced using Surfer™ (Version 7.0 for Windows 95/NT, by Golden Software Inc.). The output from Surfer™ was then imported into ArcView™ GIS (Version 3.2, by Environmental Systems Research Institute Inc.) and combined with base maps to produce the final maps. Details concerning the process used to generate the maps are provided in Part A Soil Contaminant Contour Maps.

These maps are statistical approximations of the spatial distribution of the different contaminants. Soil concentrations are only known with certainty at those sites for which soil was actually sampled and chemically analysed. The contours produced by the program are significantly affected by the spatial distribution of the sampling sites, the accuracy of the position information of the sampling sites, and the program options used to generate the contours. The accuracy of the contours diminishes at the edges of the map and in large areas where there are no or very few sample sites. In this case, the sampling density was uniform across the community inside Welland, Rodney, Davis, and Louis Streets, so the contours should be reasonably predictive of the residential soil conditions.

These maps are a very helpful tool for identifying spatial trends, particularly for very large data sets. Although useful and reasonably accurate, particularly with a high sampling density as used in this study, the contour maps are still only estimates of soil concentrations based on a statistical model. The actual soil concentration is known with certainty only at the sites where the samples were collected.

### 7.2.2 Soil Contaminant Patterns

It is evident from the contaminant contour maps, and the data in Tables 6-3 to 6-9, that soil contamination in the Rodney Street community, although extensive for some elements, tends to be patchy. Properties with much lower soil contaminant levels were often encountered between properties with much higher concentrations. Conversely, occasionally single properties with significantly elevated concentrations of some elements were surrounded by properties with much lower contaminant levels. The mechanism for the observed patchwork pattern of contamination is related to the interaction between atmospheric deposition, placement of contaminated fill, and property specific landscaping and construction activities.

Atmospheric deposition, either from fugitive or stack emissions, would result in a decreasing soil contamination gradient relative to distance from the source. Fugitive emissions can be considered a series of small point sources from vents, windows, doors or other openings in the refinery or other buildings. These are considered to be a significant potential source but are difficult to quantify. The particulates from these sources would be carried by wind currents into the surrounding community and would not necessarily be deposited evenly due to wind currents eddying around structures like trees and buildings. Particulates associated with the stack plume drop out of the plume as their weight overcomes the buoying effect of the rising gases. Depending on the wind speed, the particles will move various distances before they reach the ground. For both fugitive and stack emissions, the larger denser particles will tend to be deposited closest to the source and finer particles will tend to be carried the greatest distance. Therefore, the Rodney Street community would tend to get more deposition of larger denser particles and be affected more by fugitive emissions than more distant areas.

Atmospheric deposition by both stack and fugitive emissions was not constant over the operating life of Inco and Algoma. Releases to the local environment, particularly through fugitive emissions, were much greater in the early years of operation at both Inco and Algoma. Subsequent to the cessation of significant emissions (the Inco refinery ceased operations in 1984, and the Algoma mill in 1977) and over time through property landscaping or redevelopment, on some properties the contaminated soil would be either diluted by coverage with clean soil or removed and replaced by clean soil. Landscaping need not be elaborate to substantially alter the surface soil (top few cm) contaminant levels. Simply filling low spots in a lawn with topsoil or re-sodding can add enough clean soil to dilute the residual surficial contamination. The contamination status of undisturbed/unlandscaped properties would remain relatively unchanged, to create the soil contamination patchwork pattern that was observed across the Rodney Street community. With time, even on undisturbed properties, soil contamination deposited on the surface can work its way downwards into the lower soil horizons where it is subject to further mixing and redistribution both up and down by normal soil processes (ants, earthworms, water movement, etc.).

Also, industrial process waste could have been used to fill low areas, and since the waste can be aggregate in nature, some residents may have used it to improve drainage around homes or structures, or as construction material. Atmospheric deposition over the decades would add to the general contaminant levels on properties that did not receive fill material.

Regardless of the patchiness, some overall contaminant contour gradients and patterns are obvious. The most consistent are nickel, copper, cobalt, arsenic, and selenium. The concentrations of these five elements tended to be highest in the easterly and southeasterly areas of the Rodney Street community, adjacent to the Inco refinery. The patterns of nickel (Maps A22-A24), copper (Maps A16-A18), and cobalt (Maps A13-A15) soil contamination were particularly similar, with the higher concentrations restricted to properties along Rodney, Davis, and Mitchell Streets. The maximum soil nickel level was 17,000 µg/g detected in the 5-10 cm depth of a property on Rodney Street. The maximum soil copper concentration was 2,720 µg/g in a sample from the 10-20 cm depth of a Mitchell Street property. The highest soil cobalt concentration, also from a Mitchell Street property, was 262 µg/g in the 5-10 cm soil profile. Although properties with high nickel levels also had elevated copper and cobalt concentrations, the maxima for these elements did not occur on the same property.

The patterns of soil arsenic (Maps A4-A6) and soil selenium (Maps A25-A27) contamination were similar, with the highest levels centred on Rodney Street, and scattered contaminated properties along Mitchell Street, and a few on Davis Street. Unlike nickel, copper, and cobalt, which exceed their respective Table A effects-based guidelines on the majority of properties in the Rodney Street community, the extent of arsenic and selenium contamination was much more restricted, with concentrations that were proportionately much lower. The maximum soil arsenic concentration was 350 µg/g in the 0-5 cm depth from a property on Rodney Street. However, most soil arsenic levels were much less, with 71% of the properties in the Rodney Street community being below the Table A effects-based guideline of 20 µg/g and about 60% of the properties being within normal arsenic background concentrations. The property with the highest soil arsenic level was not the property with the highest soil nickel level.

Although a soil selenium gradient toward Inco was evident, only one property had selenium levels that exceeded the Table A effects-based guideline, with a maximum concentration of 19.4 µg/g in soil collected from the 5-10 cm depth of a property on Mitchell Street. Soil selenium levels are naturally low and therefore any elevation above background is noticeable, a fact that allowed for a contaminant gradient to become evident.

Even though soil beryllium levels exceeded the Table A effects-based guideline of 1.2 µg/g on about 49% of the properties in the Rodney Street community, unlike the other nine elements for which maps were constructed, the beryllium contaminant contour maps (Maps A7-A9) did not indicate a consistent spatial pattern, although there was a weak trend of generally slightly higher levels toward the west side of the community, but the highest individual levels occurred toward the east and northeast. The highest soil beryllium level was 4.6 µg/g, which was detected in the 10-20 cm depth at a property on Mitchell Street. Like the other metals, soil beryllium levels tended to be slightly higher at depth.

The contaminant contour maps for lead (Maps A19-A21), and to a lesser degree for cadmium (Maps A10-A12) and antimony (Maps A1-A3), did not illustrate a consistent spatial pattern or orient to specific streets, but rather identified numerous apparently random "hot spots". Soil lead levels exceeded the MOE Table A effects-based guideline of 200 µg/g on about 80% of the properties, whereas cadmium and antimony exceeded the MOE guidelines only on 1% and 2% of the properties, respectively. Even though the three elements were spatially related to each other (same general patterns on the contour maps) the soil lead concentrations were far higher than either the cadmium or antimony levels and the maximum concentrations did not occur on the same properties. For example, the maximum soil lead level was 1,800 µg/g, which occurred on Mitchell Street. The maximum soil antimony level was 35 µg/g, encountered on a Louis Street property. The maximum soil cadmium concentration was also 35 µg/g, which occurred on Davis Street. Like the other metals, these elements tended to be slightly higher at depth.

The soil iron concentrations in the Rodney Street community are quite variable and in some areas are substantially elevated. The mean iron concentration was 27,550 µg/g, which is within a normal range for Ontario, but the maximum iron level was 130,000 µg/g, or 13%. The pattern of iron distribution in soil (Maps A28 to A30) most closely resembles the nickel pattern, with the highest concentrations occurring toward the south and east, obviously centred on the homes on Rodney Street east of Fares Street. Although, both Algoma and Inco were potential iron sources, Algoma was a pig iron blast furnace, which are characteristically "dusty" operations. Iron is likely a component of the nickel feedstock from Sudbury that was processed in the Port Colborne refinery, since the Sudbury based ores, such as Pyrrhotite, an iron sulfide mineral, Pentlandite, an iron nickel sulfide mineral, Chalcopyrite, a copper iron sulfide mineral, Pyrite, an iron sulfide mineral, Magnetite, an iron oxide mineral, and Bornite, a copper iron sulfide mineral, contain iron.

### 7.3 Statistical Analysis of Chemical Relationships

Most soil concentrations tended to be slightly higher in the lower sample depths. Table 7-1 summarizes the soil concentration by sample depth and the results of two-tailed t-tests, which illustrates that the difference between depths is statistically significant for many elements. Higher concentrations at depth, particularly for elements such as nickel, copper, and cobalt which are known to be associated with Inco emissions, if they are related to atmospheric stack or fugitive emissions, suggest that the bulk of the local deposition occurred in the early operating years because the contaminants have moved down out of the upper most soil horizons. Recent or ongoing atmospheric deposition results in soil contaminants accumulating in the upper soil layers and decreasing with depth. If the origin of the soil contamination is buried waste or fill the concentrations would be substantially higher in the subsurface layers than in the surface soil.

Results of Pearson Product Correlation tests on the soil data from all depths for all chemicals are summarized in Table 7-2. Due to the very large number of degrees of freedom (1,300 plus) all "*r*" values greater than 0.08 are significantly correlated at the 95% level. The higher the *r* value the stronger the correlation between the elements. Negative *r* values indicate an inverse relationship (ie., one soil concentration increases as the other decreases).

Nickel, copper, and cobalt contamination in surface soil in the broader Port Colborne community is associated with Inco emissions. Of these three elements, nickel is a "signature" contaminant, meaning that it is present in the highest concentration over the most extensive area, and has the most consistent concentration gradient relative to distance and direction from Inco. Therefore, elements that are highly correlated with nickel are also likely related to Inco emissions.

Soil nickel concentrations in soil in the Rodney Street community are very highly correlated with soil cobalt (r=0.93), copper (r=0.87), iron (r=0.82), selenium (r=0.77), zinc (r=0.71) levels, and highly correlated with soil arsenic (r=0.60) levels, suggesting that Inco emissions are likely the principal source of these elements. The high statistical correlation is corroborated by the contaminant contour maps which strongly imply a spatial relationship between nickel, copper, cobalt, and to a lesser extent arsenic, selenium, and iron (zinc was not mapped). Previous MOE soil sampling in the Port Colborne area, identified elevated soil copper and cobalt levels as having originated from Inco (Kuja et al., 2001a; Kuja et al., 2001b). However, zinc, arsenic, selenium, and iron levels in soil in areas other than the Rodney Street community have not been shown to be consistently elevated above MOE guidelines. Arsenic levels in soil in the Inco regional plume zone are spatially and statistically related to nickel levels in soil, even though the soil arsenic levels are generally not elevated above the MOE generic Table A guideline. In the MOE report on re-sampling of soil at Humberstone School, the relationship between soil arsenic and soil nickel levels was so consistent that soil arsenic levels could be predicted by soil nickel levels within a few parts per million (MOE, 2001). The relationship between soil arsenic and soil nickel levels in the Rodney Street community, although statistically highly significant, is not quite as predictive (less consistent) as in the wider Port Colborne area downwind of the Inco stack. This suggests there may be a secondary arsenic source in the Rodney Street community.

Soil lead levels are highly correlated with zinc (r=0.75) and barium (r=0.74). These three elements are common components of older lead-based paint. Also, the historic use of leaded gasoline has substantially added to the soil lead levels in all urban areas. Even though lead was likely emitted from Inco (lead made up about 10% of a single precipitator dust sample collected and analysed in the 1970s, MOE, 1978) the lack of a lead soil spatial pattern in the Rodney Street community, and elsewhere in Port Colborne consistent with the soil nickel spatial patterns, suggests that most of the lead in the soil in the Rodney Street community is likely associated with general urban and residential sources (lead based exterior paint, disposal of battery and automotive parts, pesticide use, and leaded gasoline). Inco likely emitted lead, but it was not in the same proportion as nickel, copper, and cobalt. Any lead deposited in the Rodney Street community by Inco cannot be distinguished from general urban and residential sources.

### 7.3.1 Contaminant Groups

Scatter plots (not reproduced in this report) of the soil data were created and used with the Pearson products, principal component analysis, and the contaminant contour maps to explore the chemical inter-relations. This process suggests three distinct soil contaminant groupings in the Rodney Street community, with overlap of a few chemicals.

1) *The Nickel Group*: consisting of nickel, cobalt, copper, iron, selenium, zinc, and arsenic, are statistically related to nickel with a correlation coefficient of at least 0.50.

2) *The Lead Group*: consisting of lead, zinc, barium, and copper, are statistically related to lead

with a correlation coefficient of at least 0.50.

3) *The Aluminum Group*: consisting of aluminum, vanadium, and beryllium, are related to aluminum with a correlation coefficient of at least 0.50.

In their review of the earlier March 2001 report, Inco suggests there is a fourth chemical group, referred to as an Iron Group (Senes, 2001), which appears to be a sub-group of the MOE Nickel Group. Inco describes this iron group as consisting of iron, selenium, and arsenic, which may have originated from a mixing of different types of buried process fill from either Inco or Algoma. Inco considers this to be indicative of buried fill/process waste.

Of the various soil contaminants, arsenic is one of the most difficult to confidently attribute to a specific source in the Rodney Street community, as it has the weakest correlation coefficient with nickel of the elements in the nickel group. The property with the highest soil arsenic level is not the property with the maximum nickel concentration, and there are several properties with elevated soil arsenic and disproportionately elevated soil nickel levels (ie., five properties with soil arsenic concentrations between 75 and 150 µg/g and a soil nickel level less than 2,000 µg/g).

Table 7-3 is a summary of selected soil metal levels observed by the Ministry around specific types of heavy industry in Ontario. It clearly illustrates that in Ontario the only industries associated with substantially elevated soil nickel levels even remotely similar to levels found in Port Colborne are nickel refineries, and the only other nickel refineries in the province are the Inco and Falconbridge operations in Sudbury. Specifically, elevated soil nickel levels have not been detected around foundries similar to the Algoma foundry that operated in Port Colborne to the west of the Rodney Street community. The only other industry where measurably elevated soil nickel levels have been detected is stainless steel manufacturing, as nickel is used in the production of stainless steel. This table also illustrates that soil iron levels are significantly elevated around nickel refineries and that iron ore sintering is a source of arsenic soil contamination. Therefore, Inco is likely a significant contributing source of elevated iron levels and Algoma likely contributed to the soil arsenic levels in the Rodney Street community.

### 7.4 Results of Trench Samples

The results of chemical analysis of soil samples removed from the walls of the various trenches are summarized in Table 6-5. Based on visual identification in the field, all seven of the trenches contained some fill material, including rocks, brick pieces, metal debris, and in some cases possibly coal, coal ash, cinders, and slag. Natural undisturbed natural clay was encountered at about one metre in all trenches. The main contaminants in the trench soil are nickel, copper, cobalt, zinc, iron, and to a lesser degree lead, arsenic, and beryllium. The iron concentrations are quite elevated in some trench samples, ranging up to about 17% (168,000 µg/g at 60 cm depth from the trench on the shoulder of Rodney Street). These high iron levels possibly reflect the association with oxidized metal debris observed in some trench layers.

The two trenches from the baseball park at the south end of Rodney Street are contaminated with nickel to the bottom of the trench, a depth of about one metre, with concentrations ranging from 304 µg/g to 6,680 µg/g. The maximum arsenic level is 33.1 µg/g, the maximum copper level is 524 µg/g, and the maximum cobalt concentration is 88.8 µg/g. The nickel, copper, cobalt, and arsenic levels all tended to be higher at depth. Most other elements, notably lead, were quite low, at least relative to elsewhere in the Rodney Street community.

The trench excavated on the shoulder of Rodney Street, and the two trenches excavated in the vacant lot south of Rodney Street between Fares and Welland Streets, were similar to each other and different from the baseball park trenches in that the maximum contaminant levels tended to be closer to the surface. For example, in the trench near 124 Rodney Street the soil nickel levels ranged from 8,900 µg/g to 9,730 µg/g to a depth of approximately 35 cm and then decreased to 204 µg/g at a depth of approximately 60 cm. Similarly, the arsenic concentrations ranged from 30.7 µg/g to 43.1 µg/g in the top 65 cm, then fell to background below this depth. The contaminant levels in the trenches from the vacant field tended to be lower than in the Rodney Street and baseball park trenches. Unlike the baseball park trenches, which had high nickel levels at all depths, the trench on the shoulder of Rodney Street and both trenches in the vacant field had the highest metal levels near the surface, with the layer of contamination abruptly ending between 30 and 60 cms.

The two trenches excavated in the parkette on the east side of Welland Street tended to have lower soil contaminant levels than the other trenches. Although nickel levels were elevated to the bottom in the west trench, all other contaminants were confined to the top 65 cm. Similarly, in the east trench all the contamination was confined to the top 65 cm, falling to virtually background levels below this depth. By comparison, the soil from the trenches from the two sodded berms located on the perimeter of the parkette's basketball court was much cleaner than the other trenches. Only a few samples exceeded the MOE Table F background-based guidelines, and only a single sample exceeded the Table A effects-based guideline for beryllium.

Soil contamination was deepest in the baseball park, suggesting this area had received at least one metre of metal contaminated fill. Based on anecdotal accounts obtained from residents during the MOE's April open house, it is generally believed that the baseball park contains substantial fill. Judging by the presence of debris in the other trenches, it was evident those areas had also received some fill material, although metal contamination was mostly confined to the upper 30 to 60 cm. This suggests that outside of the baseball park, metal contaminated material may have been used more as top dressing rather than as fill, perhaps to level the ground in preparation for or subsequent to building. It is also possible that, outside of the obvious deep fill in the baseball park, the soil metal contamination in the area of the trenches south of Rodney Street is from atmospheric deposition because the contamination is largely confined to the near surface layer and this area is very close to and directly between both the Inco refinery and the historic Algoma iron foundry. If this is the case, and the soil metal levels in the broader Rodney Street community are also related to atmospheric deposition, then the soil contamination in the Rodney Street community can be expected to extend to at least 30 cm in depth. However, the only way to confidently characterize the extent of soil contamination at depth is to conduct bore hole or trench sampling at multiple locations throughout the community.

## 8.0 Soil Contamination: Source Allocation

### 8.1 Sources of Contamination

There are three potential sources of soil contamination of concern in the Rodney Street community, which include: 1) Inco; 2) Algoma; and 3) general urban/domestic sources. The Inco refinery principally emitted nickel, copper, cobalt whereas selenium, zinc and particulates were secondary. Algoma operated a blast furnace producing pig iron from 1913 to 1977. The blast furnace bordered the southwestern side of the Rodney Street community as Inco bordered the eastern side. Typical ore concentrations and oxidation/reduction operations at a blast furnace foundry would produce the following potential metal and metalloid emissions: iron, magnesium, arsenic, possibly beryllium, boron, manganese, calcium, phosphorous, sulphur, silica, plus substantial particulates (dust). In addition, there are numerous sources of contamination associated with residential communities, including lead-based paints, vehicle emissions, and pesticides.

### 8.2 Nickel, Copper, Cobalt, Arsenic, Selenium, and Zinc

The soil nickel, copper, and cobalt contamination documented in Port Colborne and the surrounding area in the 1998 and 1999 MOE investigations (Kuja et al., 2000a; Kuja et al., 2000b) is related to long term atmospheric deposition of Inco's emissions. Stack dynamics and prevailing wind patterns make the area to the northeast of Inco the zone of maximum deposition from stack emissions. The nickel:copper and nickel:cobalt soil ratios from the broad northeast area are 9.9:1 (nickel:copper) and 56:1 (nickel:cobalt), and are remarkably consistent to soil ratios from the average of all samples collected in the Rodney Street community in 2000, 10.1:1 (nickel:copper) and 51:1 (nickel:cobalt), and the trench samples, 9.5:1 (nickel:copper) and 44:1 (nickel:cobalt) (see Table 8-1). By comparison, using the natural background levels for Ontario soil (Table F in the MOE *Guideline for Use at Contaminated sites in Ontario* (MOE, 1997)) the natural ratios for these three elements in uncontaminated soil are 0.5:1 (nickel:copper) and 2.0:1 (nickel:cobalt), which illustrates the unique soil contaminant signature of Inco's Port Colborne refinery. This is very strong evidence that the nickel, copper, and cobalt contamination detected in the Rodney Street community is consistent with the soil contamination in the broader Port Colborne area downwind (to the northeast) of Inco, which are related to atmospheric emissions from Inco.

Because of the spatial distribution and the very high correlation coefficients between nickel and arsenic (r=0.60), nickel and selenium (r=0.77), and nickel and zinc (r=0.71), the elevated concentrations of arsenic, selenium, and zinc in soil in the Rodney Street community are strongly believed to have originated from Inco emissions. This is corroborated by the 1978 report (MOE

1978) that identified arsenic as 0.38% (3,800 µg/g) and zinc as 0.14% (1,400 µg/g) of Inco's refinery dust. However, soil zinc contamination can also be associated with residential sources, and so not all of the soil zinc contamination in the Rodney Street community is related to Inco. Similarly, arsenic is frequently associated with iron ore bodies and iron mineralization, and the properties with the highest soil arsenic levels are not the properties with the highest soil nickel levels. Arsenic is associated with Algoma iron ore sintering operations elsewhere in Ontario and therefore Algoma was likely a contributing source of some of the arsenic burden in the Rodney Street soil.

The spatial distribution of the nickel, copper, cobalt, selenium, and zinc, and to a lesser degree arsenic, soil contamination is consistent with a source to the south and east of the Rodney Street community, as the soil concentrations are higher on Rodney Street, Davis Street, and Mitchell Street. The zinc pattern tends to be a little more scattered but a southeasterly gradient is still apparent. In addition, the observation that the highest soil contaminant levels tended to be just below the surface (the baseball park being the exception) in the 5-10 cm or even 10-20 cm depth is consistent with an atmospheric deposition source that was much greater in the past. With the cessation of atmospheric deposition, heavy metals move down through the surface soil, although this can take decades and the downward movement is usually only a few tens of centimetres.

If the amount of metal contaminant falling onto the soil were constant and ongoing, the upper most soil layer would have the highest metal concentration because the rate of accumulation at the surface exceeds the rate of downward percolation. Fugitive and stack emissions from Inco in the early years of operation, particularly before the 152 m (500 foot) stack was constructed in 1935 (there were two 91 m (350 foot) stacks in place from 1918), would have caused high levels of atmospheric metal loading and deposition in the Rodney Street community and resulted in the rapid accumulation of heavy metals in surface soil. The main vehicle access to the Inco refinery is through the Rodney Street community, which would create substantial dust as vehicles re-entrain contaminated material from highly contaminated sites on property. The pattern of slightly higher soil metal levels on front yards may reflect the influence of re-entrainment by vehicles, surface runoff and/or contaminated snow from the roads plowed onto the shoulders or narrow front yards. When the tall stack was constructed, the impact of stack emissions on this community should have been abated and also conceivably, fugitive emissions may have been reduced, which would result in a reduced rate of metal deposition on the soil in the Rodney Street community. Eventually, the rate of accumulation in the surface soil fell below the rate of downward percolation resulting in a slow but consistent downward migration of the heavy metal contamination out of the top five cm of the surface soil and into the near-surface and sub-surface soil layers at a depth of 10 to 20 cm.

A downward percolation from the surface to subsurface soil layers after the cessation of deposition is consistent with the pattern observed in soil lead levels in Toronto. In the 1970s, lead from leaded gasoline combustion was ubiquitous in the Toronto airshed, resulting in high ambient air lead levels and subsequent deposition and accumulation of lead in surface soil. In 1971 the

MOE established a baseline soil sampling network throughout Toronto and determined that the soil lead levels were highest at the surface and decreased quickly with depth (ratio of lead in the 0-5 cm surface soil compared to the 10-15 cm soil depth was 1.6:1). Leaded gasoline was phased out in the early 1980s resulting in substantial reductions in ambient air lead levels and a virtual cessation of lead deposition to soil. A repeat sampling of the same sites in 1991 showed that with the elimination of lead deposition from the air the lead had moved down into the soil so that it was consistently higher at depth than near the surface. (ratio of lead in the surface 0-5 cm compared to the 10-15 cm soil depth having changed from 1.6:1 (1971) to 0.6:1 (1991)).

With the cessation of atmospheric deposition, contaminants should no longer accumulate at the soil surface and the fact that soil contaminant levels in the Rodney Street community tend to be higher in subsurface soil layers is a further indication that the main deposition ceased many years ago and sources of contamination are historic. However, this does not imply that over time the contaminants will continue to move downwards in the soil profile and eventually be deep enough so that they no longer pose a potential ecological or human health concern. Soil is a dynamic chemical, mechanical, and biological system, and at the microcosm scale, soil is constantly in flux. Limited MOE studies in other communities where soil has been contaminated by historic industrial air emissions have indicated that soil contaminants can move downwards through the soil by gravity and soil water percolating through soil pores, root, and insect channels. In addition, soil contaminants can be brought back to the surface from considerable depth as a result plant uptake and the tunnelling by ants, earthworms, and other soil macro and microorganisms. Earthworms alone can completely turnover the top 10 cm of soil in 100 years. The result is that over time, likely decades, soil contaminants that originated on the surface tend to move deeper in the soil and eventually get mixed into the top 30 or so centimetres of soil.

### 8.3 Lead

The elevated lead levels in soil in the Rodney Street community are not primarily related to Inco emissions. The pattern of lead contamination is not spatially similar to nickel, copper, or cobalt, and there is no southeasterly concentration gradient toward Inco. Instead, high lead levels are randomly scattered throughout the community. Lead levels in soil are highly correlated with barium, copper, cadmium, cobalt, chromium, and zinc, and comparatively poorly correlated with nickel. These elements (nickel excepted) were common anti-mildew and anti-fungal additives in paint manufactured up to the mid 1970s. Previous Phytotoxicology investigations have clearly linked residential soil contaminated by these elements to the erosion, weathering, and/or removal of exterior leaded paint. Paint chips from flaking paint are often visible on the soil. Analysis of these chips collected from residential yards of older urban homes in Toronto showed that the paint contained up to 31% lead (310,000 µg/g), 12.4% zinc (124,000 µg/g), and 0.85% chromium (8,500 µg/g) (Bisessar and McLaughlin 1995). The soil lead and zinc concentrations of these Toronto yards ranged up to 890 µg/g and 445 µg/g, respectively. Almost every year Phytotoxicology scientists assist MOE District Environmental Officers and local health unit inspectors in the investigation of blood lead poisoning of very young children. In most cases the lead source is found to be lead contaminated soil from flaking or eroded exterior lead-based paint.

Soil lead data collected from elsewhere around Port Colborne in earlier MOE soil investigations cannot be used to gauge normal residential soil lead burdens for the Rodney Street community because most of the samples were collected from boulevards and large suburban or rural lawns and therefore these data would reflect vehicle lead but not household lead. In addition, soil lead contamination is particularly characteristic of older urban residential communities, and the Rodney Street community is among the oldest in Port Colborne. Soil lead levels from newer urban/suburban communities and from outlying residential areas in Port Colborne would not have similar soil lead levels as the Rodney Street.

Lead is a ubiquitous soil contaminant that is generally higher in urban communities because of the historic use of leaded gasoline and numerous other residential lead sources. The combination of historic deposition of lead from leaded gasoline, the chronic deposition of flaking and peeling exterior leaded paint, and the use of lead-based pesticides has resulted in consistently elevated soil lead levels in urban communities across Ontario. Older urban communities have the highest soil lead levels because the soil has been exposed to greater numbers of vehicles for a longer period of time. In addition, older urban communities have higher residential density and older homes that may have been painted many times over the years, and therefore have had a longer time to accumulate weathered paint in the soil. In the Rodney Street community of Port Colborne about 80% of the properties exceed the MOE Table A generic effects-based soil lead guideline, and the average soil lead level was 222 µg/g. In Toronto, the MOE has been monitoring environmental lead levels for 25 years in a community that has no known industrial source of lead pollution. In this community, which is similar to the Rodney Street community in age and style of home construction, 78% of the residential properties exceed the MOE Table A effects-based criterion and the average soil lead level is 486 µg/g. Spuriously elevated soil lead levels are an artifact of older "residential city-core" communities and can be found in every Ontario municipality. Soil lead concentrations in the 1,000 µg/g range, such as detected at a few scattered properties in the Rodney Street community, are entirely consistent with residential lead sources and are typical of older urban communities in Ontario.

Lead was likely emitted from Inco since lead comprised 10.5% of a single Cottrell Precipitator dust sample, collected at the Inco refinery in 1978. However, based on data from soil samples collected in the Port Colborne area (Kuja et al., 2000a; and Kuja et al., 2000b), of those soil samples with soil nickel levels greater than 1,000 µg/g, the average soil nickel level was 2,120 µg/g and the average soil lead concentration was 98 µg/g, which gives a nickel:lead ratio of approximately 22:1. Similarly, using the soil data from the Rodney Street community that was collected in 2000 (excluding the trench data) the average soil nickel level was 2,545 µg/g, and the average soil lead level was 222 µg/g, which gives a nickel:lead ratio of 11.5:1. Since the nickel: lead ratio of 22:1 for the Port Colborne area in general is not the same as the nickel:lead ratio of 11.5:1 for the Rodney Street community, the lead is unlikely from the same source as the nickel contamination.

Current levels of lead in soil in Port Colborne in general, and the Rodney Street community specifically, have no consistent spatial relationship relative to Inco. Although Inco emissions may have contributed to the overall soil lead burden in the Rodney Street community, historic vehicle emissions from the combustion of leaded gasoline and residential sources, such as weathered exterior lead-based paint, are both far more significant and known lead sources that could account entirely for the soil lead levels encountered in this study, and so any Inco lead contribution cannot be measured above the normal urban lead loading.

### 8.4 Antimony

On a few properties in the Rodney Street community high soil lead levels are spatially correlated with high soil antimony concentrations. Antimony is commonly alloyed with lead as a hardening agent, and was used extensively in battery manufacture, particularly automotive lead acid batteries. Phytotoxicology investigations around secondary lead smelters that used lead acid batteries in their feed stock and around battery manufacturers, routinely identified soil lead and antimony contamination. The soil lead and soil antimony Rodney Street community contaminant contour maps illustrate a very consistent spatial relationship between these two elements. There are only two properties where antimony is substantially elevated, and both are also lead contaminated. The contamination on these two properties is almost certainly associated with lead batteries.

### 8.5 Beryllium

Although the average soil beryllium concentration in the Rodney Street community was 0.98 µg/g, which is consistent with typical Ontario background levels, a significant number of properties (49%) had soil beryllium concentrations that exceeded the Table A effects-based guideline. The source of the beryllium contamination is not known, but it could be related to slag deposited in the Rodney Street community, natural sources, and on one property, from leaded paint.

Beryllium concentrations in slag routinely range from 1 to 3 µg/g. Beryllium is also associated with coal ash. Anecdotal information suggests that slag was a common material for roadbed construction in the Rodney Street community, which may have originated at Algoma. A historic photograph of the Rodney Street community shows most of the roads in place by 1917. This photograph also illustrates that at that time the area that is now the Rodney Street community was flat, and so wide scale filling is unlikely, although "top-dressing" as discussed earlier remains a possibility on selected properties. In the recent MOE investigations, slag was observed on road shoulders, in some of the trench samples, and was occasionally encountered while sampling the residential properties. Slag like particles were identified in the scanning electron microscope photographs of soil samples collected from several Rodney Street properties. It is evident that slag is present at the surface in the Rodney Street community, and this presence could also account for the generally higher than expected soil beryllium levels.

However, the MOE has recently become aware of circumstances where elevated concentrations of naturally occurring beryllium were found to be associated with shale deposits. In view of the suspected toxicity of the metal, the presence of numerous deposits of shale in Ontario, and a practice of using shale as fill material, in 1997 MOE Phytotoxicology scientists undertook a province wide sampling program of representative shale deposits in Ontario. Seven of the twelve shale formations sampled, or 58%, had beryllium concentrations in the shale rock and the adjacent soil overburden that exceeded the MOE Table A effects-based guideline of 1.2 µg/g (McIlveen, 1997).

The highest beryllium concentration found in the province wide shale study was 3.4 µg/g, detected in samples collected from the Animikie-Gunflint shale formation in the Thunder Bay area. The Queenston and Rockcliffe shale formations, closer to Port Colborne, had beryllium concentrations ranging up to 2.3 µg/g. Only two soil samples of the 1,300 plus samples collected from the Rodney Street community had beryllium levels greater than 2.3 µg/g. The marginally elevated soil beryllium levels in this community are consistent with naturally occurring beryllium in soil derived from shale, although the number of properties with beryllium concentrations higher than the provincial background was unexpected. In addition, the soil beryllium concentrations in the Rodney Street community are very highly correlated with soil aluminum levels (r=0.79), which implies the beryllium may be primarily natural in origin.

The highest soil beryllium concentration detected in the Rodney Street community was 4.6 µg/g, which occurred on a property that had significantly elevated soil lead levels (877 µg/g). This property also had high arsenic, barium, nickel, cobalt, copper, and zinc concentrations. Although soil lead levels and soil beryllium levels across the Rodney Street community are not highly correlated (r=0.29), the spatial relationship between beryllium and lead at this single property is not likely coincidental (compare beryllium Maps A7, A8, and A9 with lead Maps A19, A20, and A21). It is certain that the beryllium levels on this property are not related to Inco emissions because the statistical relationships between soil beryllium and soil nickel (r=0.08), soil beryllium and copper (r=0.16), as well as, soil beryllium and cobalt (r=0.11) are less significant than the soil beryllium and lead relationship (r=0.29). In addition, beryllium and arsenic soil levels are actually inversely related (negative correlation coefficient, r=-0.03, as arsenic levels increase beryllium levels decrease, and vice versa). Soil beryllium levels are more highly correlated with barium (r=0.60) than with antimony (r=0.10), which suggests that the elevated lead and beryllium levels on this property are related to paint rather than batteries. Although the high beryllium levels in soil on this property appear to be related to leaded paint, which is not the case elsewhere in the Rodney Street community because other than this single property there is no consistent spatial relationship between soil beryllium and soil lead concentrations. With the exception of this one property, the marginally elevated beryllium levels in soil in the Rodney Street community are believed to be a combination of natural levels of some local shale inclusions, surficially scattered slag and coal ash.

## 9.0 Conclusions

The soil nickel concentration in the Rodney Street community averages about 2,500 µg/g and the predominant form of nickel in the soil in the Rodney Street community is nickel oxide (80% of the total nickel, on average).

Property by property sampling revealed substantial variation in both the numbers of contaminants and the soil contaminant concentrations. Of the more than 1,300 samples collected from approximately 200 properties, about 99% of the properties had soil nickel levels that exceed the MOE generic Table A effects-based criterion of 200 µg/g. The maximum soil nickel level was 17,000 µg/g. In addition to nickel, the MOE Table A effects-based guidelines were exceeded for lead on approximately 80% of the properties, cobalt on 62% of the properties, copper on 54% of the properties, beryllium on 49% of the properties, arsenic on 29% of the properties, zinc on 17% of the properties, antimony on 2% of the properties, selenium on 1% of the properties and cadmium on 1% of the properties. For most elements on most properties, the soil contaminant concentrations tended to increase with depth. If the trenches excavated in the vacant lot south of Rodney Street and the park east of Welland Street are representative of the soil profiles across the community then soil contamination on residential properties in the Rodney Street community may extend to 30 cm, but should decrease rapidly below that depth.

Inco is the source of soil nickel, copper, and cobalt, contamination in the Rodney Street community. The elevated soil arsenic levels are principally Inco related. However, emissions from Algoma were probably a secondary source and likely contributed to the elevated soil arsenic levels on some properties in the Rodney Street community. Because of the high degree of spatial and statistical relationship of selenium and zinc with these four elements (nickel, copper, cobalt and arsenic), then the elevated soil selenium and possibly zinc levels are also believed to be related to Inco.

The baseball park at the southwest corner of Rodney and Davis Streets was, at least partially, created from metal contaminated fill. Similarly, because of the long history of industry ownership of the land and the location relative to the two sources, some of the properties on the south side of Rodney Street may also have been affected by fill. In contrast, the source of the soil nickel, copper, cobalt, and likely arsenic, selenium and zinc contamination across the broader Rodney Street community is believed to be fugitive Inco emissions that occurred early in the refinery's operating history, and not fill. Regardless of the mechanism of contamination (fill or atmospheric deposition) the nickel, copper and cobalt originated from Inco. The height of the tall stack, constructed in 1935, in conjunction with the strong southwesterly prevailing winds in non-snow season, dispersed most of the stack emissions to the northeast after the stack was built, resulting in the soil contaminant pattern across the Port Colborne area documented in the 1998 and 1999 MOE soil investigations (Kuja et al., 2000a; Kuja et al., 2000b). However, fugitive emissions from the refinery would have had a local influence. At the MOE open house in April 2001, many anecdotal observations were offered by long time Rodney Street community residents and refinery employees about the chronically dusty conditions in the Rodney Street community and at the Inco refinery during the earlier years of Inco operation. Since the community was literally sandwiched between two large industries (Inco and Algoma) that were dusty by nature, particularly in the past before the technology was implemented to control fugitive emissions or the concern was realized about environmental or occupational health exposure, there is no reason to doubt the anecdotal comments about the Rodney Street community being a dusty neighbourhood in the refinery's early years.

The highest soil nickel, copper, cobalt, arsenic, selenium, and zinc soil concentrations occurred on properties in the south and eastern areas of the Rodney Street community along Rodney, Mitchell, and Davis Streets. Based on the contaminant contour maps it is likely that elevated soil metal levels may extend slightly further along Davis Street north of Louis Street. Further soil sampling is also warranted in the residential communities immediately adjacent to the north-northwest, north, and north-northeast of Inco.

In Ontario, the only industries associated with substantially elevated soil nickel levels even remotely similar to levels found in Port Colborne are nickel refineries, and the only other nickel refineries in the province are the Inco and Falconbridge operations in Sudbury. Elevated soil nickel levels have not been detected around foundries similar to the Algoma foundry that operated in Port Colborne to the west of the Rodney Street community.

The randomly scattered soil lead contamination observed in the Rodney Street community is primarily related to domestic residential lead sources and not to Inco emissions. The erosion and flaking of old lead-based paint from exterior structures such as house and shed walls, porches, fences, poles, and playground equipment is a common source of soil lead contamination in older urban communities. The soil lead levels found in the Rodney Street community are not unusual, either in extent or concentration, relative to other similarly aged older urban communities in Ontario. On properties where the soil lead levels were elevated the concentrations of cadmium (elevated above background, only a single result above Table A), chromium, copper, barium, and zinc often were proportionately elevated. Along with lead, these elements were common pigment, anti-mildew, or anti-fungal additives in old exterior paint and are frequent co-contaminants in residential soil. Antimony was another element that was highly correlated with lead, although it exceeded MOE guidelines on only three properties. Antimony is commonly alloyed with lead, particularly in lead acid batteries. Lead and antimony soil contamination is an indication that batteries may have been stored or disposed of on the property, whereas lead and barium, and lead and zinc soil contamination is a signature of lead-based paint.

Although the average soil beryllium level in the Rodney Street community was comparable to the provincial soil background concentration, almost one half of the properties exceeded the MOE Table A effects-based guideline. Soil beryllium levels marginally above the guideline are not unusual, because the guideline and the upper end of the background range are the same (1.2 µg/g). Also, MOE investigations have documented that shale, and soil derived from shale, regularly exceed the guideline. In addition, slag and coal ash can have a beryllium concentration that is above the guideline, and slag is present at the surface across the Rodney Street community. Slag was believed to have been used as roadbed material. With the exception of one property where elevated beryllium levels were concurrent with high lead and other heavy metals, the marginally elevated soil beryllium concentrations across the Rodney Street community are related to the presence of slag and local shale deposits. Emissions from Algoma may have contributed to the generally marginally elevated soil beryllium levels in the Rodney Street community.

Other than the properties on the south side of Rodney Street, the "patchwork" pattern of high and low soil contamination on neighbouring lots is likely related to fugitive emissions and property maintenance and landscaping. Adding topsoil or mulch, re-sodding, building, and cultivating gardens are landscaping practices that, over time, tend to cover or dilute contaminants that are predominantly present in the surface soil. It also indicates that the source of the soil contamination is likely atmospheric and that with recent deposition substantially decreased, newly landscaped properties have not become re-contaminated to the levels of undisturbed properties.

The bio-availability of nickel to plants growing in nickel-contaminated soil in Port Colborne is very low, in the range of less than 1% (this refers to the plant bio-availability discussed in Part A Section 5.3.3, not the human stomach leach bioaccessibility discussed in Part B Appendix 5). This means the nickel has a low mobility in the soil, which means it would not be readily taken up by plants. This low bio-availability accounts for the remarkably minor amount of nickel injury observed on species of vegetation known to be sensitive to nickel in areas of Port Colborne where the soil nickel levels are substantially above the MOE ecotox-based soil guideline.

## 9.1 Conclusions Related to the Stated Objectives

There were four specific objectives of Part A of the report stated in Section 1.0.

1) *To determine the extent and severity of soil metal and arsenic contamination in the Rodney Street community of Port Colborne*. Although an overall spatial pattern was evident for some contaminants, particularly nickel, copper, cobalt, and arsenic (see the soil contaminant contour maps) there was considerable property by property variability. The surficial soil contamination above the intervention level of nickel in the Rodney Street community is at least 20 cm deep but is less likely to extend beyond 30 cm in depth.

2) *To characterize metal soil contamination in the Rodney Street community.* The metal contaminants can be statistically divided into the following three groups: 1) the Nickel Group (nickel, cobalt, copper, iron, selenium, zinc, and arsenic); 2) the Lead Group (lead, zinc, barium, and copper); and 3) the Aluminum Group (aluminum, vanadium, and beryllium). The metals within each of these groups could be from a common source type.

The soil nickel, copper, and cobalt soil contamination in the Rodney Street community is very similar in metal:metal ratios (but higher in absolute concentrations) to the soil contamination downwind of the Inco refinery. This is very strong evidence that the nickel, copper, and cobalt contamination detected in the Rodney Street community is consistent with the soil contamination in the broader Port Colborne area downwind (to the northeast) of Inco. Although the concentration of nickel, copper and cobalt has a patchy distribution in the Rodney Street community, there is a gradient of decreasing concentration of these metals in surface soil with distance from Inco. The soil arsenic and lead concentrations in the Rodney Street community are higher than elsewhere in Port Colborne implying an additional/alternative source.

3) *To determine to the extent possible the source(s) of the soil contamination in the Rodney Street community*. With respect to the Nickel Group of metals, Inco is the source of the soil nickel, copper, and cobalt contamination above Ontario background levels. Inco is the likely source of the elevated soil zinc and selenium levels. Also, Inco is likely the main source of the arsenic contamination; Algoma is a contributing source. Inco and Algoma are both likely sources of the elevated iron levels. Regarding the Lead Group of metals, although Inco likely emitted lead it cannot be differentiated from the many residential sources of urban lead. The soil lead contamination in the Rodney Street community is typical of older urban residential communities in Ontario; the sources are numerous and property specific (ie., paint, pesticide use, storage, maintenance, and disposal of vehicles and vehicle parts (particularly batteries), historic use of leaded gasoline). Slightly elevated soil beryllium levels are related to natural shale deposits with a contribution from Algoma slag/particulates. The Aluminium Group metals are most likely related to a natural soil origin.

4) *To determine to the extent possible the mechanisms(s) of soil contamination in the Rodney Street community.* The predominant mechanism of soil nickel, cobalt, copper and to a lesser degree iron, selenium, arsenic and zinc contamination in the Rodney Street community is believed to be atmospheric deposition of Inco emissions, with contributions from fugitive and stack emissions. Atmospheric deposition of Algoma emissions (both stack and fugitive emissions) contributed to the soil arsenic and iron contamination in the Rodney Street community. The contamination in the Rodney Street baseball park is fill, likely from Inco waste. Some of the properties on the south side of Rodney Street, particularly the back yards, may have been influenced by shallow filling or spreading of Inco or Algoma waste. Regardless of the mechanism(s) of contamination, Inco is the only source of substantially elevated nickel concentrations in the Rodney Street community.

## Conclusions Summary

- Inco is the source of nickel, copper, and cobalt soil contamination in the Rodney Street community
- the mechanism of the soil contamination at depth in the baseball park at the southwest corner of Rodney and Davis Streets is industrial process waste/fill
- Inco is the predominant source of arsenic, selenium, zinc and iron soil contamination in the Rodney Street community, Algoma is a contributing source of arsenic and iron contamination
- the predominant mechanism of the soil nickel, copper, cobalt, arsenic, selenium, and zinc contamination in the Rodney Street community is atmospheric deposition of Inco emissions
- most of the surficial soil contamination in the Rodney Street community, excluding the properties on Rodney Street, is associated with fugitive emissions, contributions from stack emissions were likely secondary
- the soil lead contamination in the Rodney Street community is typical of older urban residential communities in Ontario; the sources are numerous and property specific (eg., paint, pesticide use, storage, maintenance, and disposal of vehicles and vehicle parts (particularly batteries), historic use of leaded gasoline)
- the surficial soil contamination in the Rodney Street community is between 20 and 30 cm deep (may be deeper on the south side of Rodney Street).
- the soil contamination on some properties (particularly the back yards) on the south side of Rodney Street is likely associated with or been affected by industrial process waste/fill
- Inco emitted lead, and some lead in soil in the Rodney Street community is likely from Inco emissions, but the contribution can not be measured above the typical urban residential soil lead burden
- the generally elevated soil beryllium concentrations are associated with natural shale deposits and dust/slag (likely) predominantly from Alogoma
- most of the surficial soil contamination in the Rodney Street community occurred earlier in Inco's and Algoma's operating history

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**Table 5-1: Minimum Number of Soil Core Sections per Yard**

| Number of Yards per Property | Single Composite Sample | Duplicate Sample | Triplicate Sample |
|---|---|---|---|
| 1 Yard | 27<br>(1 yard X 9 cores X 3 depths) | 54<br>(1 yard X 9 cores X 2 replicates X 3 depths) | 81<br>(1 yard X 9 cores X 3 replicates X 3 depths) |
| 2 Yards | 54<br>(2 yards X 9 cores X 3 depths) | 108<br>(2 yards X 9 cores X 2 replicates X 3 depths) | 162<br>(2 yards X 9 cores X 3 replicates X 3 depths) |
| 3 Yards | 81<br>(3 yards X 9 cores X 3 depths) | 162<br>(3 yards X 9 cores X 2 replicates X 3 depths) | 243<br>(3 yards X 9 cores X 3 replicates X 3 depths) |
| Assuming 9 cores per yard (this was minimum number), and all three depths could be sampled. | | | |

## Table 6-1: Nickel Speciation Results for Selected Rodney Street Community Soil Samples

| Sample Number | Nickel Concentration | | | | | | |
|---|---|---|---|---|---|---|---|
| | MOE[1] Total Nickel (µg/g) | Lakefield Research Limited | | | | | SSRL[2] Nickel Oxide (% of Total Nickel) |
| | | Total Nickel (µg/g) | Soluble Nickel (% of Total Nickel) | Nickel Sulfide (% of Total Nickel) | Nickel Metal (% of Total Nickel) | Nickel Oxide (% of Total Nickel) | |
| **Processed Samples[5]** | | | | | | | |
| 772 | 6,630 | 6,000 | 0.32 | 7.02 | 7.98 | 84.6 | NS |
| 799 | 6,590 | 5,300 | 0.35 | 8.88 | 7.03 | 83.8 | NS |
| 1332 | 10,400 | 10,300 | 0.57 | 6.65 | 5.11 | 87.6 | NS |
| 1348 | 9,760 | 7,900 | 0.33 | 9.46 | 14.10 | 76.1 | NS |
| 1408 | 10,800 | 10,600 | 0.26 | 6.35 | 38.70 | 54.6 | 943 |
| 1415 | 6,450 | 6,200 | 0.28 | 6.30 | 6.16 | 87.3 | NS |
| 3740 | 9,300 | 7,900 | 0.65 | 5.96 | 5.96 | 87.4 | 854 |
| 3768 | 6,930 | 6,000 | 0.29 | 10.50 | 10.60 | 78.6 | NS |
| 3770 | 8,680 | 7,400 | 0.36 | 6.02 | 5.93 | 87.7 | NS |
| 3821 | 6,670 | 6,600 | 0.29 | 9.50 | 11.60 | 78.6 | NS |
| **Mean** | **8,221** | **7,420** | **0.37** | **7.66** | **11.30** | **80.6** | |
| **Bulk Samples (not processed)[6]** | | | | | | | |
| 772 | NS | 7,900 | 0.44 | 8.40 | 5.75 | 85.4 | NS |
| 799 | NS | 3,500 | 0.77 | 16.50 | 5.77 | 76.9 | NS |
| 1332 | NS | 8,300 | 0.27 | 15.10 | 3.70 | 81.0 | NS |
| 1348 | NS | 7,900 | 0.27 | 18.90 | 16.20 | 64.7 | NS |
| 1408 | NS | 12,200 | 0.32 | 7.62 | 4.01 | 88.0 | NS |
| 1415 | NS | 9,300 | 0.27 | 10.80 | 5.97 | 83.0 | NS |
| 3740 | NS | 7,700 | 0.68 | 11.80 | 5.64 | 81.9 | NS |
| 3768 | NS | 6,700 | 0.34 | 12.10 | 7.34 | 80.2 | NS |
| 3770 | NS | 5,000 | 0.49 | 14.50 | 3.93 | 81.1 | NS |
| 3821 | NS | 6,300 | 0.39 | 12.60 | 4.52 | 82.5 | NS |
| **Mean** | **NS** | **7,800** | **0.42** | **12.80** | **6.28** | **80.5** | NS |

1. MOE Laboratory Services Branch **total nickel** by ICP-MS.
2. Stanford Synchrotron Radiation Laboratory **nickel oxide** by XAFS (X-Ray Absorption Fine Structure).
3. Mean of 3 replicate analysis of the same sample (R1= 100%, R2=87%, R3=95%).
4. Mean of 3 replicate analysis of the same sample (R1=91%, R2=87%, R3=76%).
5. Dried, ground, and sieved, following MOE standard protocol for processing soil.
6. Dried, but not processed.

NS=No Sample.

**Table 6-2: Metal and Arsenic Concentration of Inco Port Colborne 1978 Refinery Dust**

| Dust Origin | Dust Composition (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Arsenic | Cobalt | Copper | Iron | Lead | Nickel | Sulfur | Zinc |
| **Tumblast Stack Dust**<br>- two major phases identified, a magnesium-silicon alloy (50% nickel) and a nickel-magnesium alloy (80% nickel).<br>- minor nickel-silicon-magnesium iron phase. | NL | 0.24 | 0.14 | 2.62 | NL | 42.9 | <0.20 | NL |
| **Cobalt Multiclone Stack Dust**<br>- major phase is cobalt sulfate hydrate.<br>- minor phases are cobaltous oxide and iron hydrogen sulfate hydrate. | NL | 28.7 | <0.02 | 4.7 | NL | 0.53 | 17.7 | NL |
| **Cottrell Precipitator Dust**<br>- most prevalent compound is nickel oxide.<br>- lead sulfate is also a major phase.<br>- nickel sulfate and copper sulfate are minor phases. | 0.38 | 0.66 | 7.6 | 0.61 | 10.48 | 38.7 | 7.06 | 0.14 |
| **Submerged Combustion Evaporator Stack**<br>- an aqueous slurry, when dried the only compound detected was nickel oxide. | NL | NL | 0.04 | 0.23 | NL | 72.2 | 0.76 | NL |
| Based on dust samples provided to MOE by Inco from the Port Colborne refinery (MOE 1978).<br>NL=Not listed. | | | | | | | | |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2022013 (Front yard) | 0-5 cm | 5200 | na | **35** | 100 | <0.25 | 0.50 | 11000 | 35 | **120** | **610** | 58000 | **280** | 3200 | 800 | 2.1 | **6400** | 5.70 | 41 | 24 | 660 |
| | 0-5 cm | 5200 | na | **37.0** | 110 | <0.25 | 0.70 | 12000 | 37 | **110** | **470** | 53000 | **300** | 3400 | 800 | 2.2 | **5500** | 5.70 | 38 | 24 | 620 |
| | 5-10 cm | 5500 | na | **65.0** | 130 | 0.6 | <0.10 | 9900 | 49 | **220** | **990** | 130000 | **400** | 3200 | 1200 | 3.7 | **16000** | 6.90 | 37 | 34 | **1100** |
| | 5-10 cm | 5800 | na | **110.0** | 140 | 0.6 | 0.40 | 11000 | 44 | **160** | **770** | 90000 | **480** | 3300 | 1100 | 3.0 | **9200** | 8.70 | 41 | 29 | **990** |
| | 10-15 cm | 7300 | na | **30.0** | 99 | <0.25 | <0.10 | 11000 | 19 | **57** | **430** | 38000 | 190 | 4000 | 560 | <0.25 | **4900** | 3.90 | 36 | 24 | 420 |
| | 10-15 cm | 7500 | na | **42.0** | 140 | 0.6 | <0.10 | 12000 | 36 | **84** | **660** | 51000 | **240** | 3900 | 740 | 1.4 | **7100** | 5.10 | 42 | 25 | 620 |
| | 15-20 cm | 7100 | na | 18.0 | 90 | <0.25 | 0.50 | 17000 | 20 | 30 | 200 | 26000 | 100 | 4400 | 400 | 1.3 | **2100** | 2.50 | 45 | 21 | 260 |
| | 15-20 cm | 6800 | na | 13.0 | 78 | <0.25 | 0.30 | 16000 | 15 | 18 | 130 | 17000 | 140 | 4000 | 300 | <0.25 | **1200** | 2.10 | 42 | 19 | 170 |
| 2022014 (Back yard) | 0-5 cm | 7800 | na | 15.0 | 67 | <0.25 | 0.50 | 14000 | 22 | 48 | 210 | 30000 | 93 | 4800 | 470 | 0.8 | **2400** | 2.80 | 49 | 24 | 340 |
| | 0-5 cm | 6700 | na | 20.0 | 68 | <0.25 | 0.60 | 14000 | 24 | 49 | 240 | 30000 | 99 | 4700 | 500 | 1.2 | **2600** | 3.80 | 49 | 21 | 330 |
| | 5-10 cm | 5900 | na | 20.0 | 74 | <0.25 | 0.40 | 15000 | 23 | **58** | 260 | 31000 | 110 | 4500 | 490 | 1.1 | **2800** | 3.90 | 59 | 21 | 390 |
| | 5-10 cm | 5500 | na | **32.0** | 87 | <0.25 | <0.10 | 16000 | 28 | **96** | **420** | 53000 | 170 | 4400 | 640 | 1.5 | **5100** | 8.70 | 64 | 24 | 520 |
| | 10-15 cm | 6800 | na | **28.0** | 100 | 0.6 | 0.50 | 20000 | 29 | **110** | **390** | 45000 | 180 | 5400 | 650 | 1.9 | **4300** | 5.20 | 86 | 28 | 550 |
| | 10-15 cm | 5600 | na | **29.0** | 99 | <0.25 | 0.40 | 16000 | 27 | **100** | **410** | 47000 | **220** | 3700 | 650 | 1.5 | **4400** | 5.50 | 82 | 26 | 550 |
| | 15-20 cm | 7900 | na | **39.0** | 150 | 0.7 | 0.50 | 25000 | 35 | **150** | **590** | 56000 | **260** | 5700 | 930 | 2.3 | **6600** | 5.80 | 140 | 32 | 720 |
| | 15-20 cm | 5500 | na | **38.0** | 100 | <0.25 | <0.10 | 18000 | 24 | **110** | **410** | 50000 | **240** | 3700 | 610 | 1.0 | **5600** | 5.50 | 87 | 27 | 600 |
| 2022501 (Front yard) | 0-5 cm | 7100 | na | 14.0 | 90 | <0.25 | 0.90 | 16000 | 19 | 36 | 160 | 26000 | 98 | 6600 | 530 | 0.8 | **1700** | 2.70 | 42 | 23 | 320 |
| | 0-5 cm | 8100 | na | 13.0 | 80 | 0.6 | 1.00 | 17000 | 20 | 39 | 170 | 27000 | 110 | 7200 | 550 | 0.6 | **1700** | 2.80 | 45 | 28 | 330 |
| | 5-10 cm | 7100 | na | 16.0 | 72 | <0.25 | 1.10 | 17000 | 23 | 41 | 180 | 30000 | 95 | 7000 | 550 | 0.9 | **1800** | 2.80 | 41 | 25 | 340 |
| | 5-10 cm | 8400 | na | 15.0 | 82 | 0.6 | 1.10 | 18000 | 21 | 44 | 190 | 29000 | 110 | 7400 | 580 | 0.8 | **1800** | 2.60 | 47 | 27 | 360 |
| | 10-15 cm | 8700 | na | 18.0 | 87 | 0.6 | 0.90 | 20000 | 22 | **56** | 250 | 35000 | 120 | 7700 | 670 | <0.25 | **2800** | 2.80 | 49 | 29 | 430 |
| | 10-15 cm | 8800 | na | 18.0 | 93 | 0.7 | 1.10 | 20000 | 26 | 50 | 230 | 32000 | 120 | 7600 | 650 | 1.2 | **2300** | 3.30 | 51 | 28 | 410 |
| 2022502 (Back yard) | 0-5 cm | 10000 | na | 23.0 | 100 | 0.6 | 1.10 | 8400 | 30 | **58** | 260 | 40000 | 130 | 3900 | 700 | 1.4 | **3100** | 4.60 | 26 | 32 | 410 |
| | 0-5 cm | 9500 | na | 19.0 | 84 | 0.6 | 0.90 | 8800 | 29 | **51** | 240 | 36000 | 120 | 3800 | 620 | <0.25 | **2700** | 4.20 | 27 | 29 | 380 |
| | 5-10 cm | 10000 | na | 26.0 | 89 | 0.6 | 0.80 | 7500 | 30 | **57** | 290 | 42000 | 120 | 3900 | 690 | 1.1 | **3300** | 5.10 | 23 | 31 | 400 |
| | 5-10 cm | 10000 | na | 23.0 | 86 | 0.6 | 0.50 | 8700 | 32 | **57** | 290 | 44000 | 130 | 3900 | 720 | 1.4 | **3300** | 5.00 | 26 | 31 | 430 |
| | 10-15 cm | 16000 | na | 16.0 | 110 | 0.8 | 0.80 | 6900 | 30 | 42 | 180 | 35000 | 84 | 4800 | 700 | 0.8 | **2200** | 3.40 | 23 | 39 | 270 |
| | 10-15 cm | 13000 | na | 16.0 | 93 | 0.7 | 0.70 | 9700 | 31 | 49 | 220 | 38000 | 110 | 4800 | 660 | 0.9 | **2800** | 2.80 | 27 | 34 | 330 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2022601 (Front yard) | 0-5 cm | 8700 | na | 11.0 | 83 | <0.25 | 0.40 | 15000 | 17 | 38 | 170 | 24000 | 100 | 5700 | 400 | 0.8 | **1900** | 2.30 | 71 | 25 | 250 |
| | 0-5 cm | 8500 | na | 10.0 | 77 | <0.25 | 0.40 | 14000 | 17 | 34 | 150 | 22000 | 94 | 5400 | 370 | <0.25 | **1600** | 2.40 | 58 | 23 | 230 |
| | 5-10 cm | 6800 | na | 22.0 | 87 | <0.25 | 0.60 | 18000 | 25 | **63** | 280 | 36000 | 120 | 6700 | 540 | 1.3 | **3100** | 3.70 | 88 | 27 | 350 |
| | 5-10 cm | 8600 | na | 20.0 | 100 | 0.6 | 0.60 | 18000 | 23 | **70** | 300 | 34000 | 130 | 6800 | 590 | 1.1 | **3200** | 3.90 | 84 | 29 | 340 |
| | 10-15 cm | 6100 | na | **43.0** | 88 | <0.25 | 0.30 | 16000 | 34 | **110** | **600** | 55000 | 160 | 5700 | 750 | 1.9 | **6700** | 4.70 | 78 | 28 | 590 |
| | 10-15 cm | 7300 | na | **45.0** | 120 | 0.6 | 0.40 | 18000 | 36 | **160** | **640** | 72000 | 180 | 6200 | 870 | 2.6 | **8400** | 5.40 | 80 | 32 | 610 |
| 2022602 (Back yard) | 0-5 cm | 10000 | na | 5.6 | 78 | <0.25 | 0.60 | 35000 | 16 | 20 | 61 | 17000 | 61 | 11000 | 430 | <0.25 | **330** | 1.00 | 120 | 26 | 110 |
| | 0-5 cm | 10000 | na | 4.2 | 73 | <0.25 | 0.50 | 32000 | 16 | 18 | 50 | 16000 | 53 | 10000 | 390 | <0.25 | **300** | 1.00 | 120 | 26 | 96 |
| | 5-10 cm | 8700 | na | 5.9 | 66 | <0.25 | 0.60 | 30000 | 15 | 29 | 82 | 15000 | 77 | 11000 | 380 | <0.25 | **680** | 1.60 | 97 | 26 | 110 |
| | 5-10 cm | 8500 | na | 5.4 | 62 | <0.25 | 0.50 | 29000 | 15 | 17 | 55 | 15000 | 57 | 10000 | 320 | <0.25 | **380** | 1.20 | 92 | 26 | 91 |
| | 10-15 cm | 9700 | na | 6.1 | 83 | 0.6 | 0.40 | 35000 | 17 | 25 | 85 | 16000 | 79 | 12000 | 350 | <0.25 | **570** | 1.30 | 130 | 28 | 110 |
| | 10-15 cm | 14000 | na | 10.0 | 120 | 0.9 | 1.50 | 37000 | 25 | **51** | 170 | 25000 | 170 | 13000 | 490 | 1.1 | **1200** | 2.70 | 250 | 40 | 280 |
| 2022701 (Front yard) | 0-5 cm | 8800 | na | 15.0 | 88 | <0.25 | 0.80 | 11000 | 20 | 41 | 190 | 28000 | 150 | 3900 | 430 | <0.25 | **2200** | 3.40 | 46 | 23 | 350 |
| | 0-5 cm | 8400 | na | 15.0 | 86 | <0.25 | 0.70 | 10000 | 23 | 41 | 180 | 28000 | 140 | 3900 | 410 | 1.3 | **2200** | 3.50 | 45 | 23 | 330 |
| | 5-10 cm | 9100 | na | 18.0 | 88 | <0.25 | 0.60 | 9400 | 27 | 46 | 220 | 32000 | 150 | 3700 | 470 | 0.9 | **2700** | 3.80 | 41 | 24 | 380 |
| | 5-10 cm | 9500 | na | 24.0 | 120 | 0.6 | 0.80 | 11000 | 32 | **68** | **320** | 44000 | 200 | 4100 | 550 | 1.6 | **4300** | 5.20 | 47 | 27 | 500 |
| | 10-15 cm | 6700 | na | **27.0** | 110 | <0.25 | 0.70 | 13000 | 21 | 47 | 280 | 32000 | **210** | 4300 | 470 | 1.5 | **3200** | 5.20 | 48 | 20 | 440 |
| | 10-15 cm | 7000 | na | **39.0** | 120 | <0.25 | 1.00 | 13000 | 27 | **60** | **340** | 42000 | **260** | 3800 | 600 | 0.9 | **4100** | 5.90 | 53 | 21 | 590 |
| 2022702 (Back yard) | 0-5 cm | 9100 | na | 14.0 | 110 | <0.25 | 0.90 | 6800 | 21 | 47 | 210 | 23000 | 170 | 2600 | 350 | 0.8 | **2400** | 3.70 | 39 | 24 | 370 |
| | 0-5 cm | 8300 | na | 13.0 | 100 | <0.25 | 0.60 | 6000 | 18 | 36 | 160 | 19000 | 130 | 2300 | 280 | 0.8 | **1700** | 3.60 | 36 | 20 | 330 |
| | 5-10 cm | 12000 | na | 21.0 | 130 | 0.6 | 1.10 | 7100 | 29 | **61** | 270 | 32000 | 180 | 3000 | 450 | 1.1 | **3000** | 4.60 | 43 | 30 | 460 |
| | 5-10 cm | 12000 | na | 15.0 | 130 | 0.6 | 0.90 | 6900 | 25 | 49 | 220 | 27000 | 150 | 2900 | 390 | 1.1 | **2600** | 3.70 | 42 | 28 | 390 |
| | 10-15 cm | 12000 | na | 20.0 | 130 | 0.6 | 1.20 | 7500 | 27 | **58** | 280 | 33000 | 180 | 3100 | 440 | <0.25 | **3000** | 4.40 | 47 | 28 | 440 |
| | 10-15 cm | 12000 | na | 20.0 | 150 | 0.7 | 1.20 | 7700 | 29 | **60** | 280 | 34000 | 190 | 3300 | 470 | 0.8 | **3200** | 4.30 | 49 | 30 | 450 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2022801 (Front yard) | 0-5 cm | 8400 | na | 11.0 | 75 | <0.25 | 0.40 | 13000 | 18 | 33 | 140 | 24000 | 90 | 5400 | 460 | 0.8 | **1700** | 2.00 | 40 | 25 | 200 |
| | 0-5 cm | 8000 | na | 9.5 | 76 | <0.25 | 0.50 | 14000 | 16 | 33 | 140 | 23000 | 86 | 5500 | 420 | 1.1 | **1600** | 2.10 | 41 | 24 | 190 |
| | 5-10 cm | 7600 | na | **26.0** | 92 | 0.6 | 0.60 | 16000 | 26 | **66** | 300 | 45000 | 170 | 6000 | 650 | 1.6 | **3800** | 4.10 | 61 | 26 | 460 |
| | 5-10 cm | 7800 | na | 23.0 | 95 | 0.6 | 0.30 | 17000 | 25 | **71** | 300 | 45000 | 170 | 6200 | 610 | 1.4 | **4100** | 4.00 | 52 | 27 | 400 |
| | 10-15 cm | 7700 | na | **34.0** | 97 | 0.6 | <0.10 | 17000 | 31 | **91** | **410** | 61000 | 180 | 5700 | 710 | 2.3 | **6200** | 4.80 | 59 | 28 | 540 |
| | 10-15 cm | 8900 | na | 24.0 | 110 | 0.7 | 0.30 | 19000 | 20 | **59** | 300 | 36000 | 150 | 6400 | 550 | 0.7 | **4000** | 3.90 | 64 | 28 | 340 |
| 2022802 (Back yard) | 0-5 cm | 15000 | na | 13.0 | 120 | 1 | 0.70 | 35000 | 27 | **56** | 190 | 27000 | 130 | 14000 | 490 | 1.0 | **1700** | 2.80 | 170 | 39 | 210 |
| | 0-5 cm | 14000 | na | 15.0 | 120 | 1 | 0.60 | 38000 | 25 | **59** | 210 | 29000 | 140 | 14000 | 530 | <0.25 | **1900** | 3.10 | 190 | 37 | 240 |
| | 5-10 cm | 18000 | na | 13.0 | 140 | 1.1 | 0.50 | 37000 | 29 | 44 | 160 | 28000 | 120 | 15000 | 460 | 0.6 | **1400** | 2.70 | 190 | 41 | 190 |
| | 5-10 cm | 18000 | na | 12.0 | 140 | 1.1 | 0.60 | 46000 | 30 | 41 | 170 | 29000 | 120 | 17000 | 500 | 1.0 | **1300** | 2.40 | 240 | 40 | 180 |
| | 10-15 cm | 19000 | na | 10.0 | 140 | 1.1 | 0.50 | 43000 | 69 | 29 | 120 | 27000 | 89 | 15000 | 420 | 9.8 | **940** | 2.10 | 260 | 43 | 140 |
| | 10-15 cm | 20000 | na | 11.0 | 150 | 1.2 | 0.70 | 49000 | 28 | 31 | 140 | 27000 | 99 | 18000 | 470 | 0.9 | **1100** | 2.00 | 210 | 42 | 170 |
| 2022901 (Front yard) | 0-5 cm | 8200 | na | 14.0 | 100 | <0.25 | 0.50 | 7200 | 22 | 36 | 140 | 20000 | 96 | 2900 | 290 | <0.25 | **1700** | 1.70 | 27 | 22 | 240 |
| | 0-5 cm | 7900 | na | 13.0 | 81 | <0.25 | 0.50 | 7300 | 16 | 34 | 130 | 20000 | 87 | 3000 | 280 | 0.6 | **1600** | 1.90 | 27 | 22 | 230 |
| | 5-10 cm | 7000 | na | 18.0 | 85 | <0.25 | 0.30 | 8400 | 19 | **52** | 200 | 29000 | 120 | 3300 | 390 | 1.0 | **2600** | 2.80 | 27 | 23 | 320 |
| | 5-10 cm | 8800 | na | 14.0 | 99 | <0.25 | 0.50 | 8200 | 19 | 48 | 180 | 24000 | 120 | 3300 | 380 | 1.0 | **2300** | 1.80 | 29 | 24 | 300 |
| | 10-15 cm | 7500 | na | **62.0** | 130 | 0.6 | 0.40 | 14000 | 32 | **97** | **470** | 55000 | **230** | 4700 | 710 | 1.8 | **5800** | 5.60 | 46 | 26 | 690 |
| | 10-15 cm | 7300 | na | **60.0** | 130 | 0.6 | 0.40 | 13000 | 33 | **100** | **480** | 59000 | **230** | 4400 | 720 | 2.2 | **6000** | 6.30 | 42 | 27 | 710 |
| 2023001 (Front yard) | 0-5 cm | 6700 | na | 16.0 | 140 | <0.25 | 0.90 | 79000 | 45 | 47 | 220 | 29000 | **240** | 5900 | 430 | 1.3 | **2400** | 2.90 | 580 | 22 | 400 |
| | 0-5 cm | 7500 | na | 16.0 | 140 | 0.6 | 1.10 | 91000 | 21 | 45 | 210 | 29000 | **200** | 5800 | 450 | 0.8 | **2200** | 3.20 | 690 | 24 | 380 |
| | 5-10 cm | 6200 | na | 24.0 | 150 | 0.6 | 0.30 | 77000 | 26 | **72** | **340** | 48000 | **220** | 5600 | 580 | 1.6 | **4700** | 4.30 | 590 | 26 | 480 |
| | 5-10 cm | 6800 | na | **33.0** | 160 | 0.6 | 0.60 | 74000 | 25 | **73** | **400** | 48000 | **260** | 6200 | 670 | 1.4 | **4600** | 4.90 | 560 | 26 | 550 |
| | 10-15 cm | 5700 | na | **39.0** | 180 | 0.6 | 0.50 | 39000 | 28 | **79** | **480** | 50000 | **320** | 5400 | 690 | 1.6 | **5500** | 5.10 | 270 | 25 | 650 |
| | 10-15 cm | 5800 | na | **40.0** | 190 | 0.6 | <0.10 | 34000 | 32 | **110** | **550** | 66000 | **330** | 6700 | 830 | 2.0 | **9000** | 4.10 | 220 | 28 | 730 |

### Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2023101 (Front yard) | 0-5 cm | 4800 | na | 14.0 | 77 | <0.25 | 0.40 | 12000 | 17 | 33 | 180 | 18000 | 130 | 4100 | 310 | 1.2 | **1700** | 2.60 | 31 | 17 | 280 |
| | 0-5 cm | 4300 | na | 14.0 | 68 | <0.25 | 1.00 | 10000 | 17 | 29 | 150 | 18000 | 110 | 3500 | 300 | 0.8 | **1600** | 2.40 | 27 | 16 | 250 |
| | 5-10 cm | 4400 | na | 19.0 | 92 | <0.25 | <0.10 | 14000 | 19 | **52** | 260 | 28000 | 170 | 4400 | 420 | 0.8 | **2800** | 3.00 | 34 | 19 | 380 |
| | 5-10 cm | 4400 | na | 15.0 | 94 | <0.25 | 0.40 | 14000 | 19 | **56** | 280 | 32000 | 180 | 4400 | 440 | 1.1 | **3200** | 2.90 | 36 | 22 | 380 |
| | 10-15 cm | 5000 | na | 18.0 | 120 | <0.25 | <0.10 | 16000 | 23 | **72** | **360** | 48000 | 200 | 4800 | 570 | 1.5 | **5100** | 3.40 | 43 | 33 | 470 |
| | 10-15 cm | 4300 | na | 17.0 | 120 | <0.25 | <0.10 | 15000 | 20 | **59** | **330** | 34000 | 180 | 4500 | 460 | 1.0 | **4000** | 3.00 | 38 | 23 | 400 |
| 2023102 (Back yard) | 0-5 cm | 4100 | na | 22.0 | 100 | <0.25 | 0.30 | 9500 | 21 | **64** | **330** | 38000 | **260** | 2600 | 490 | 1.4 | **4000** | 4.40 | 39 | 20 | 500 |
| | 0-5 cm | 3700 | na | 22.0 | 100 | <0.25 | <0.10 | 8300 | 18 | **63** | **320** | 33000 | **270** | 2100 | 470 | 1.3 | **3900** | 5.80 | 36 | 17 | 480 |
| | 5-10 cm | 4200 | na | **36.0** | 120 | <0.25 | <0.10 | 10000 | 26 | **91** | **460** | 52000 | **330** | 2700 | 610 | 1.6 | **6100** | 5.50 | 43 | 24 | 610 |
| | 5-10 cm | 4400 | na | **37.0** | 120 | <0.25 | 0.30 | 9700 | 28 | **95** | **480** | 56000 | **310** | 2400 | 640 | 2.4 | **6100** | 5.60 | 42 | 25 | 630 |
| | 10-15 cm | 4200 | na | **39.0** | 130 | <0.25 | <0.10 | 11000 | 31 | **88** | **460** | 48000 | **360** | 2500 | 630 | 2.3 | **6100** | 5.80 | 51 | 22 | 600 |
| | 10-15 cm | 3900 | na | **44.0** | 110 | <0.25 | <0.10 | 9900 | 21 | **91** | **420** | 45000 | **310** | 2400 | 540 | 1.6 | **6400** | 5.40 | 41 | 20 | 540 |
| 2023201 (Front yard) | 0-5 cm | 10000 | na | **30.0** | 120 | 0.7 | 0.30 | 19000 | 27 | **79** | **360** | 41000 | 160 | 6200 | 640 | 1.6 | **4200** | 5.80 | 66 | 31 | 420 |
| | 0-5 cm | 9600 | na | **26.0** | 120 | 0.7 | 0.40 | 19000 | 28 | **84** | **360** | 46000 | 170 | 6400 | 680 | 3.2 | **4400** | 5.50 | 57 | 31 | 450 |
| | 5-10 cm | 10000 | na | **37.0** | 120 | 0.7 | <0.10 | 18000 | 29 | **86** | **410** | 48000 | 160 | 5500 | 690 | 1.5 | **5800** | 6.50 | 64 | 29 | 460 |
| | 5-10 cm | 9700 | na | **49.0** | 120 | 0.7 | <0.10 | 17000 | 31 | **110** | **480** | 61000 | 200 | 5400 | 750 | 1.7 | **7700** | 5.80 | 56 | 31 | 520 |
| | 10-15 cm | 11000 | na | 20.0 | 180 | 1.1 | <0.10 | 32000 | 17 | 50 | 300 | 36000 | 130 | 6100 | 680 | <0.25 | **4300** | 3.90 | 97 | 28 | 320 |
| | 10-15 cm | 13000 | na | 28.0 | 240 | **1.6** | <0.10 | 40000 | 18 | **63** | **430** | 39000 | 180 | 6500 | 850 | 0.6 | **5400** | 4.80 | 120 | 28 | 420 |
| 2023202 (Back yard) | 0-5 cm | 8900 | na | 11.0 | 96 | <0.25 | 0.50 | 13000 | 17 | 30 | 140 | 21000 | 100 | 3800 | 440 | 0.9 | **1600** | 2.60 | 37 | 27 | 240 |
| | 0-5 cm | 8700 | na | 9.9 | 110 | <0.25 | 0.60 | 14000 | 17 | 26 | 120 | 19000 | 110 | 3800 | 440 | 0.6 | **1300** | 2.90 | 38 | 25 | 220 |
| | 5-10 cm | 7300 | na | 12.0 | 92 | <0.25 | 0.30 | 17000 | 18 | 36 | 170 | 24000 | 140 | 4000 | 460 | <0.25 | **2000** | 2.50 | 44 | 26 | 260 |
| | 5-10 cm | 7300 | na | 10.0 | 80 | <0.25 | 0.40 | 18000 | 16 | 29 | 120 | 22000 | 110 | 3600 | 440 | <0.25 | **1600** | 2.10 | 42 | 26 | 190 |
| | 10-15 cm | 5800 | na | **30.0** | 100 | <0.25 | 0.40 | 12000 | 21 | **61** | 240 | 33000 | 160 | 3900 | 410 | 0.9 | **3000** | 5.00 | 37 | 29 | 370 |
| | 10-15 cm | 5700 | na | 18.0 | 93 | <0.25 | 0.60 | 14000 | 22 | 40 | 190 | 24000 | **210** | 3600 | 370 | 0.8 | **2200** | 4.00 | 39 | 26 | 280 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2023301 (Front yard) | 0-5 cm | 5900 | na | **37.0** | 99 | 0.6 | <0.10 | 16000 | 31 | **140** | **540** | 67000 | **220** | 5800 | 830 | 2.4 | **7000** | 5.90 | 40 | 30 | 590 |
| | 0-5 cm | 6200 | na | **61.0** | 110 | 0.6 | 0.40 | 16000 | 42 | **170** | **670** | 78000 | **240** | 5600 | 1000 | 3.2 | **8000** | 8.10 | 43 | 34 | 700 |
| | 5-10 cm | 6100 | na | **86.0** | 120 | 0.6 | <0.10 | 14000 | 46 | **230** | **970** | 130000 | **360** | 5500 | 1100 | 3.9 | **17000** | 7.90 | 37 | 30 | **1000** |
| | 5-10 cm | 5900 | na | **78.0** | 94 | <0.25 | 0.30 | 16000 | 32 | **120** | **640** | 66000 | **290** | 5900 | 800 | 2.9 | **8800** | 7.40 | 37 | 24 | 700 |
| | 10-15 cm | 5900 | na | 25.0 | 70 | <0.25 | <0.10 | 21000 | 19 | **72** | **350** | 45000 | 130 | 6700 | 500 | 1.6 | **5100** | 3.70 | 44 | 22 | 360 |
| | 10-15 cm | 5700 | na | 25.0 | 67 | <0.25 | <0.10 | 19000 | 15 | **51** | 280 | 32000 | 95 | 6700 | 420 | 0.8 | **3500** | 4.40 | 37 | 19 | 290 |
| 2023302 (Back yard) | 0-5 cm | 4700 | na | 19.0 | 68 | <0.25 | <0.10 | 7300 | 22 | **84** | 290 | 39000 | 140 | 2000 | 490 | 1.2 | **3500** | 4.40 | 25 | 26 | 360 |
| | 0-5 cm | 3900 | na | **29.0** | 65 | <0.25 | <0.10 | 6200 | 22 | **84** | 280 | 30000 | 120 | 1400 | 450 | 1.7 | **3100** | 4.80 | 24 | 17 | 310 |
| | 5-10 cm | 4700 | na | **56.0** | 100 | <0.25 | 0.30 | 9400 | 34 | **110** | **500** | 66000 | **330** | 2100 | 660 | 2.6 | **6800** | 6.20 | 31 | 23 | 630 |
| | 5-10 cm | 3900 | na | **30.0** | 69 | <0.25 | <0.10 | 5500 | 25 | **66** | **330** | 41000 | 140 | 1400 | 470 | 2.2 | **4300** | 4.10 | 22 | 16 | 400 |
| | 10-15 cm | 4200 | na | 20.0 | 46 | <0.25 | <0.10 | 5300 | 17 | 44 | 200 | 27000 | 120 | 1300 | 300 | 1.0 | **2800** | 3.20 | 21 | 19 | 260 |
| | 10-15 cm | 3200 | na | 9.5 | 30 | <0.25 | <0.10 | 3900 | 9 | 19 | 97 | 12000 | 59 | 990 | 180 | <0.25 | **1100** | 1.70 | 15 | 12 | 130 |
| 2023401 (Back yard) | 0-5 cm | 9100 | na | **350.0** | 180 | 0.7 | <0.10 | 18000 | 150 | **160** | **860** | 57000 | **280** | 3800 | 860 | 2.0 | **6600** | 3.40 | 66 | 33 | 710 |
| | 0-5 cm | 7300 | na | **77.0** | 130 | 0.7 | <0.10 | 11000 | 54 | **160** | **580** | 68000 | 160 | 2400 | 860 | 2.2 | **7000** | 6.30 | 44 | 31 | 590 |
| | 5-10 cm | 12000 | na | **69** | 310 | 1 | 0.50 | 15000 | 63 | **220** | **970** | 99000 | **390** | 4100 | 1300 | 3.7 | **11000** | 7.8 | 67 | 44 | **1200** |
| | 5-10 cm | 10000 | na | **62** | 150 | 0.8 | <0.10 | 9500 | 49 | **160** | **680** | 98000 | 190 | 3400 | 1000 | 3.7 | **8700** | 7.5 | 41 | 37 | 780 |
| | 10-15 cm | 13000 | na | **69** | 160 | 0.9 | <0.10 | 13000 | 47 | **120** | **630** | 72000 | **230** | 5100 | 900 | 2.4 | **7600** | 6.6 | 53 | 40 | 650 |
| | 10-15 cm | 14000 | na | 32 | 160 | 0.8 | <0.10 | 13000 | 31 | **91** | **470** | 55000 | 160 | 4800 | 640 | 0.9 | **5700** | 6 | 50 | 37 | 470 |
| 2023501 (Front yard) | 0-5 cm | 9000 | na | **36.0** | 180 | 0.7 | 0.30 | 29000 | 33 | **120** | **530** | 49000 | **310** | 11000 | 850 | 2.1 | **6200** | 7.30 | 100 | 32 | 670 |
| | 0-5 cm | 8500 | na | **37.0** | 180 | 0.8 | <0.10 | 28000 | 40 | **160** | **660** | 69000 | **370** | 11000 | 1000 | 2.6 | **8600** | 7.50 | 85 | 35 | **810** |
| | 5-10 cm | 11000 | na | **67.0** | 210 | 1 | <0.10 | 30000 | 57 | **200** | **1000** | 90000 | **400** | 10000 | 1200 | 3.4 | **14000** | 8.60 | 95 | 39 | **1100** |
| | 5-10 cm | 12000 | na | **53.0** | 200 | 1 | <0.10 | 29000 | 45 | **180** | **840** | 93000 | **370** | 10000 | 1000 | 3.7 | **13000** | 8.40 | 100 | 41 | **1000** |
| | 10-15 cm | 12000 | na | **48.0** | 200 | 0.9 | <0.10 | 33000 | 36 | **130** | **1000** | 60000 | **300** | 10000 | 960 | 1.7 | **12000** | 7.10 | 100 | 36 | **830** |
| | 10-15 cm | 9500 | na | **48.0** | 190 | 0.8 | <0.10 | 29000 | 27 | **140** | **980** | 62000 | **360** | 8400 | 1100 | 2.3 | **11000** | 6.00 | 110 | 32 | **840** |
| 2023502 (Back yard) | 0-5 cm | 9800 | na | 22.0 | 240 | 0.7 | 0.70 | 17000 | 28 | **70** | **480** | 38000 | **460** | 3900 | 510 | 1.7 | **6000** | 5.20 | 90 | 29 | 720 |
| | 0-5 cm | 9700 | na | 21.0 | 220 | 0.6 | 0.60 | 15000 | 26 | **65** | **400** | 37000 | **400** | 3700 | 470 | 1.9 | **4400** | 4.90 | 81 | 28 | 680 |
| | 5-10 cm | 11000 | na | 19.0 | 240 | 0.7 | 0.30 | 17000 | 27 | **68** | **430** | 37000 | **410** | 3900 | 490 | 1.8 | **4700** | 5.20 | 90 | 30 | 660 |
| | 5-10 cm | 9900 | na | 20.0 | 200 | 0.6 | 0.40 | 16000 | 25 | **64** | **390** | 34000 | **380** | 3600 | 450 | 1.0 | **4300** | 4.60 | 82 | 28 | 600 |
| | 10-15 cm | 10000 | na | 20.0 | 230 | 0.7 | 0.60 | 25000 | 28 | **69** | **390** | 40000 | **380** | 4800 | 510 | 1.5 | **4400** | 6.80 | 94 | 30 | 620 |
| | 10-15 cm | 12000 | na | 17.0 | 210 | 0.7 | <0.10 | 39000 | 26 | **64** | 300 | 35000 | **310** | 6700 | 540 | 1.0 | **3400** | 3.50 | 110 | 31 | 480 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2023601 (Rodney St ball diamond) | 0-5 cm | 5100 | na | **29.0** | 72 | <0.25 | <0.10 | 10000 | 20 | **140** | **560** | 43000 | 110 | 2700 | 440 | 1.4 | **7700** | 6.20 | 42 | 25 | 400 |
| | 0-5 cm | 5300 | na | **29.0** | 71 | <0.25 | <0.10 | 10000 | 20 | **130** | **540** | 39000 | 110 | 2700 | 450 | 1.1 | **6400** | 5.40 | 46 | 25 | 390 |
| | 5-10 cm | 5000 | na | **33.0** | 72 | <0.25 | <0.10 | 13000 | 21 | **150** | **630** | 49000 | 110 | 3600 | 460 | 1.3 | **8600** | 6.20 | 52 | 27 | 420 |
| | 5-10 cm | 5500 | na | **32.0** | 74 | <0.25 | <0.10 | 14000 | 21 | **140** | **640** | 42000 | 110 | 3800 | 460 | 1.1 | **7500** | 6.50 | 62 | 25 | 430 |
| | 10-15 cm | 5500 | na | **33.0** | 75 | <0.25 | <0.10 | 16000 | 22 | **130** | **610** | 42000 | 100 | 4500 | 410 | 1.7 | **7400** | 6.70 | 74 | 26 | 400 |
| | 10-15 cm | 6100 | na | **35.0** | 74 | <0.25 | <0.10 | 20000 | 21 | **130** | **600** | 41000 | 99 | 5600 | 430 | 1.3 | **7300** | 7.00 | 97 | 27 | 370 |
| 2023701 (Front yard) | 0-5 cm | 10000 | na | 16.0 | 110 | 0.6 | <0.10 | 20000 | 23 | **71** | 290 | 29000 | 160 | 7200 | 480 | <0.25 | **3900** | 3.90 | 54 | 30 | 370 |
| | 0-5 cm | 10000 | na | 16.0 | 120 | 0.7 | <0.10 | 23000 | 23 | **85** | **340** | 31000 | 170 | 8200 | 530 | 1.0 | **4200** | 4.60 | 61 | 30 | 420 |
| | 5-10 cm | 12000 | na | 22.0 | 130 | 0.7 | <0.10 | 23000 | 25 | **85** | **340** | 32000 | 200 | 7500 | 510 | 1.2 | **4500** | 4.30 | 64 | 32 | 430 |
| | 5-10 cm | 9700 | na | 23.0 | 120 | 0.6 | <0.10 | 25000 | 23 | **96** | **400** | 34000 | 200 | 7500 | 530 | 1.6 | **5600** | 4.70 | 68 | 30 | 440 |
| | 10-15 cm | 10000 | na | **73.0** | 160 | 0.8 | <0.10 | 22000 | 42 | **210** | **1000** | 77000 | **350** | 6600 | 980 | 3.0 | **14000** | 8.30 | 68 | 34 | **930** |
| | 10-15 cm | 10000 | na | **56.0** | 150 | 0.7 | <0.10 | 23000 | 29 | **160** | **780** | 48000 | **310** | 6500 | 720 | 2.5 | **11000** | 8.80 | 81 | 31 | 690 |
| 2023702 (Back yard) | 0-5 cm | 9000 | na | 13.0 | 110 | 0.7 | <0.10 | 23000 | 18 | **53** | 230 | 23000 | 180 | 7400 | 400 | 0.9 | **2600** | 5.20 | 120 | 29 | 320 |
| | 0-5 cm | 7300 | na | 11.0 | 90 | <0.25 | <0.10 | 18000 | 14 | 48 | 190 | 25000 | 130 | 6200 | 370 | 0.8 | **2700** | 2.90 | 73 | 26 | 270 |
| | 5-10 cm | 7900 | na | 12.0 | 100 | 0.6 | <0.10 | 24000 | 17 | 45 | 190 | 24000 | 200 | 7800 | 400 | 0.8 | **2600** | 2.20 | 120 | 27 | 280 |
| | 5-10 cm | 9000 | na | 15.0 | 110 | 0.7 | <0.10 | 27000 | 16 | 45 | 210 | 25000 | 130 | 8000 | 440 | 1.1 | **2500** | 2.70 | 100 | 29 | 310 |
| | 10-15 cm | 8100 | na | 12.0 | 120 | 0.6 | 0.30 | 27000 | 15 | 39 | 180 | 23000 | **280** | 8000 | 380 | <0.25 | **2300** | 2.30 | 140 | 27 | 280 |
| | 10-15 cm | 9200 | na | 14.0 | 120 | 0.7 | 0.30 | 26000 | 16 | **53** | 230 | 25000 | 200 | 7200 | 430 | 1.0 | **2700** | 2.70 | 98 | 30 | 340 |
| 2023801 (Front yard) | 0-5 cm | 18000 | na | 12.0 | 120 | 0.9 | 0.70 | 9900 | 27 | 47 | 150 | 25000 | 91 | 6000 | 390 | 1.0 | **1800** | 2.30 | 37 | 40 | 190 |
| | 0-5 cm | 20000 | na | **130.0** | 120 | 0.9 | 0.60 | 7900 | 27 | 43 | 130 | 24000 | 83 | 5000 | 360 | 0.8 | **1600** | 2.10 | 36 | 41 | 180 |
| | 5-10 cm | 21000 | na | **100.0** | 120 | 0.9 | 0.40 | 7100 | 26 | 29 | 89 | 25000 | 50 | 5900 | 410 | <0.25 | **1000** | 1.50 | 29 | 43 | 140 |
| | 5-10 cm | 22000 | na | **82.0** | 130 | 0.9 | 0.70 | 5500 | 28 | 19 | 61 | 26000 | 39 | 5600 | 400 | <0.25 | **600** | 1.10 | 27 | 45 | 110 |
| | 10-15 cm | 22000 | na | **110.0** | 130 | 0.9 | 0.50 | 6100 | 27 | 25 | 90 | 27000 | 46 | 5900 | 400 | <0.25 | **1000** | 1.30 | 29 | 45 | 130 |
| | 10-15 cm | 21000 | na | **130.0** | 130 | 0.9 | <0.10 | 6200 | 27 | 24 | 93 | 27000 | 43 | 6000 | 400 | 0.8 | **1100** | 1.20 | 28 | 45 | 130 |
| 2023802 (Back yard) | 0-5 cm | 16000 | na | 16.0 | 190 | 0.9 | 0.90 | 14000 | 26 | **79** | **320** | 30000 | **320** | 5800 | 480 | 1.2 | **4300** | 3.80 | 51 | 36 | 520 |
| | 0-5 cm | 17000 | na | 18.0 | 200 | 0.9 | 0.70 | 13000 | 30 | **83** | **340** | 32000 | **300** | 5700 | 480 | 1.3 | **4600** | 5.30 | 55 | 39 | 530 |
| | 5-10 cm | 19000 | na | 15.0 | 200 | 1 | 0.40 | 12000 | 30 | **75** | **310** | 33000 | **280** | 6300 | 520 | 1.0 | **4200** | 3.20 | 44 | 43 | 470 |
| | 5-10 cm | 18000 | na | 20.0 | 210 | 0.9 | 0.50 | 13000 | 28 | **84** | **460** | 34000 | **300** | 6300 | 550 | 0.6 | **4700** | 0.30 | 48 | 41 | 540 |
| | 10-15 cm | 15000 | na | **32.0** | 230 | 1 | 0.30 | 18000 | 27 | **110** | **530** | 41000 | **410** | 6200 | 580 | 1.7 | **7500** | 0.30 | 66 | 37 | 690 |
| | 10-15 cm | 13000 | na | **42.0** | 270 | 1.1 | 0.50 | 23000 | 37 | **140** | **740** | 49000 | **560** | 5700 | 640 | 2.1 | **11000** | 0.40 | 110 | 35 | **940** |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2023901 (Back yard) | 0-5 cm | 12000 | na | 6.5 | 80 | 0.6 | <0.10 | 24000 | 18 | 46 | 120 | 18000 | 36 | 9200 | 460 | <0.25 | **1100** | <0.1 | 42 | 30 | 110 |
| | 0-5 cm | 12000 | na | 10.0 | 84 | 0.6 | <0.10 | 21000 | 17 | 47 | 170 | 20000 | 38 | 7700 | 510 | <0.25 | **1400** | <0.1 | 39 | 30 | 130 |
| | 5-10 cm | 19000 | na | 7.7 | 110 | 0.9 | 0.70 | 24000 | 24 | 29 | 88 | 23000 | 27 | 12000 | 460 | <0.25 | **780** | <0.1 | 56 | 40 | 97 |
| | 5-10 cm | 20000 | na | 11.0 | 120 | 0.9 | 0.50 | 22000 | 26 | 40 | 130 | 25000 | 35 | 12000 | 540 | <0.25 | **1200** | <0.1 | 49 | 42 | 110 |
| | 10-15 cm | 18000 | na | 11.0 | 110 | 0.9 | 0.40 | 30000 | 42 | 39 | 150 | 24000 | 39 | 13000 | 480 | 0.8 | **1600** | <0.1 | 60 | 39 | 110 |
| | 10-15 cm | 20000 | na | 11.0 | 120 | 1 | 0.30 | 17000 | 29 | **64** | 240 | 29000 | 48 | 9800 | 540 | <0.25 | **2300** | <0.1 | 43 | 44 | 140 |
| 2024101 (Back yard) | 0-5 cm | 11000 | na | 13 | 120 | 0.6 | <0.10 | 14000 | 22 | **70** | 250 | 21000 | 140 | 5500 | 360 | 0.9 | **3000** | 4.2 | 43 | 26 | 310 |
| | 0-5 cm | 13000 | na | 11 | 130 | 0.7 | 1.00 | 15000 | 25 | **70** | 260 | 23000 | 150 | 6200 | 410 | <0.25 | **3100** | 3.1 | 43 | 30 | 300 |
| | 5-10 cm | 14000 | na | 14 | 140 | 0.8 | 0.40 | 20000 | 26 | **64** | 270 | 27000 | 160 | 9200 | 420 | 0.9 | **3200** | 3.7 | 47 | 34 | 350 |
| | 5-10 cm | 12000 | na | 14 | 130 | 0.7 | <0.10 | 21000 | 23 | **61** | 260 | 24000 | 130 | 8200 | 390 | <0.25 | **3500** | 3.2 | 45 | 30 | 260 |
| | 10-15 cm | 12000 | na | 34 | 180 | 0.8 | 0.30 | 19000 | 28 | **87** | **460** | 43000 | **280** | 6900 | 640 | 1.3 | **5900** | 3.9 | 57 | 33 | 520 |
| | 10-15 cm | 14000 | na | 19 | 160 | 0.8 | 0.30 | 28000 | 25 | **60** | **330** | 31000 | 140 | 11000 | 480 | <0.25 | **3600** | 3 | 60 | 36 | 370 |
| | 15-20 cm | 8900 | na | **27** | 120 | 0.6 | <0.10 | 17000 | 24 | **80** | **490** | 37000 | 160 | 5600 | 550 | 0.9 | **6100** | 5.2 | 62 | 33 | 380 |
| | 15-20 cm | 9200 | na | **38** | 260 | 0.6 | <0.10 | 16000 | 26 | **97** | **670** | 38000 | **210** | 5500 | 520 | 1.6 | **7800** | 5.2 | 58 | 33 | 450 |
| 2024201 (Side yard) | 0-5 cm | 13000 | na | **29.0** | 190 | 1 | 0.50 | 30000 | 38 | **84** | **400** | 34000 | **420** | 9200 | 620 | 1.4 | **5000** | 4.40 | 89 | 33 | 540 |
| | 0-5 cm | 13000 | na | **28.0** | 180 | 1 | 0.50 | 32000 | 36 | **90** | **410** | 35000 | **330** | 9800 | 620 | 1.3 | **6300** | 4.20 | 85 | 33 | 540 |
| | 5-10 cm | 10000 | na | **27.0** | 200 | 0.8 | <0.10 | 28000 | 31 | **110** | **530** | 38000 | **440** | 7800 | 590 | 1.3 | **8200** | 5.30 | 74 | 27 | 610 |
| | 5-10 cm | 12000 | na | **29.0** | 200 | 0.9 | <0.10 | 30000 | 34 | **96** | **460** | 38000 | **440** | 8700 | 620 | 1.1 | **7600** | 5.80 | 81 | 30 | 540 |
| | 10-15 cm | 12000 | na | **29.0** | 190 | 0.9 | <0.10 | 32000 | 26 | **96** | **460** | 39000 | **330** | 8100 | 630 | 1.2 | **8600** | 5.00 | 77 | 28 | 610 |
| | 10-15 cm | 18000 | na | 20.0 | 200 | 1.2 | <0.10 | 33000 | 29 | **55** | 250 | 31000 | **230** | 11000 | 600 | <0.25 | **3800** | 3.50 | 84 | 37 | 380 |
| | 15-20 cm | 19000 | na | 18.0 | 200 | **1.4** | 0.40 | 31000 | 26 | 45 | 220 | 31000 | **340** | 8300 | 550 | <0.25 | **3500** | 3.40 | 100 | 35 | 370 |
| | 15-20 cm | 18000 | na | 18.0 | 190 | 1.2 | <0.10 | 37000 | 35 | **54** | 250 | 33000 | **300** | 11000 | 620 | <0.25 | **3200** | 2.60 | 90 | 35 | 360 |
| 2024601 (Back yard) | 0-5 cm | 12000 | na | 17.0 | 390 | 0.8 | 2.20 | 24000 | 36 | 38 | **370** | 31000 | **650** | 6500 | 450 | 1.3 | **2300** | 3.80 | 130 | 33 | **1200** |
| | 0-5 cm | 12000 | na | 21.0 | 420 | 0.8 | 2.40 | 25000 | 41 | 41 | **380** | 31000 | **740** | 6900 | 480 | 0.9 | **2200** | 4.50 | 140 | 34 | **1300** |
| | 5-10 cm | 11000 | na | 17.0 | 400 | 0.8 | 2.30 | 26000 | 36 | 36 | **360** | 30000 | **600** | 6900 | 410 | 1.3 | **1900** | 3.60 | 140 | 32 | **1100** |
| | 5-10 cm | 11000 | na | 19.0 | 360 | 0.9 | 2.20 | 22000 | 34 | 42 | **430** | 38000 | **650** | 6400 | 430 | 1.6 | **3000** | 4.80 | 130 | 33 | **1200** |
| | 10-15 cm | 12000 | na | 19.0 | 580 | 0.8 | 2.60 | 29000 | 44 | 35 | **430** | 40000 | **890** | 8700 | 500 | 1.8 | **2000** | 4.40 | 170 | 36 | **1300** |
| | 10-15 cm | 10000 | na | 20.0 | 340 | 0.9 | 2.20 | 22000 | 34 | 38 | **410** | 34000 | **670** | 6500 | 400 | 1.5 | **2400** | 4.50 | 150 | 33 | **1000** |
| | 15-20 cm | 14000 | na | 19.0 | 400 | 1.2 | 2.60 | 22000 | 38 | 35 | **420** | 38000 | **700** | 6400 | 470 | 1.1 | **2200** | 4.20 | 180 | 42 | **960** |
| | 15-20 cm | 10000 | na | 23.0 | 380 | 0.9 | 2.60 | 21000 | 34 | 48 | **410** | 46000 | **870** | 5700 | 460 | 1.9 | **3200** | 5.10 | 160 | 33 | **1100** |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292316 (Front | 0-5 cm | 15000 | <0.4 | 9.0 | 154 | 1.1 | 0.75 | 27600 | 23 | 22 | 104 | 22500 | **213** | 13000 | 461 | 4.5 | **401** | <0.3 | 113 | 33 | 183 |
| 2292317 (Front yard) | 0-5 cm | 17000 | <0.4 | 10.5 | 150 | 1 | 1.41 | 17700 | 32 | 48 | 235 | 22500 | **238** | 7740 | 459 | 3.7 | **1680** | <0.3 | 63 | 34 | 394 |
| | 5-10 cm | 19100 | <0.4 | 9.7 | 159 | 1.2 | 1.37 | 17100 | 32 | 48 | 246 | 24700 | **206** | 7850 | 463 | 3.7 | **1670** | <0.3 | 64 | 39 | 368 |
| | 10-20 cm | 25100 | <0.4 | 10.5 | 201 | 1.5 | 1.29 | 17500 | 37 | 43 | **337** | 30100 | 188 | 9150 | 420 | 3.7 | **1670** | <0.3 | 75 | 50 | 379 |
| 2292318 (Back yard) | 0-5 cm | 19300 | <0.4 | 10.0 | 184 | 1.2 | 1.36 | 18100 | 32 | 35 | 164 | 26800 | 192 | 6820 | 446 | 3.9 | **1320** | <0.3 | 71 | 38 | 314 |
| | 5-10 cm | 21100 | <0.4 | 9.4 | 179 | 1.2 | 1.17 | 22900 | 32 | 31 | 139 | 27300 | 154 | 7290 | 437 | 3.7 | **1080** | <0.3 | 70 | 41 | 263 |
| | 10-20 cm | 20200 | <0.4 | 12.2 | 196 | 1.2 | 1.51 | 16600 | 33 | 36 | 174 | 28900 | 184 | 6940 | 412 | 3.7 | **1670** | <0.3 | 69 | 40 | 318 |
| 2292319 (Front yard) | 0-5 cm | 17500 | <0.4 | 10.9 | 145 | 1.1 | 1.34 | 19400 | 28 | 49 | 231 | 24700 | **201** | 8220 | 520 | 3.7 | **1850** | <0.3 | 58 | 35 | 291 |
| | 5-10 cm | 19800 | <0.4 | 11.4 | 153 | 1.1 | 1.37 | 23100 | 29 | 50 | 236 | 26800 | **203** | 9020 | 555 | 3.8 | **1920** | <0.3 | 65 | 39 | 287 |
| | 10-20 cm | 18700 | <0.4 | 15.1 | 174 | 1.2 | 1.56 | 22500 | 28 | **57** | **301** | 28300 | **249** | 8880 | 538 | 4.0 | **2700** | 0.50 | 75 | 37 | 327 |
| 2292320 (Back yard) | 0-5 cm | 20800 | <0.4 | 17.3 | 288 | **1.8** | 2.17 | 19400 | 35 | **51** | **333** | 29400 | **377** | 7320 | 466 | 3.9 | **2300** | <0.3 | 114 | 43 | 593 |
| | 5-10 cm | 19900 | <0.4 | 17.8 | 293 | **1.6** | 2.13 | 20300 | 34 | **52** | **391** | 30700 | **369** | 7220 | 497 | 4.2 | **2670** | 0.30 | 116 | 40 | 610 |
| | 10-20 cm | 19600 | <0.4 | 21.2 | 267 | **1.6** | 2.10 | 24500 | 31 | 46 | **380** | 30700 | **336** | 7400 | 486 | 3.9 | **2790** | 0.60 | 125 | 39 | 498 |
| 2292321 (Front yard) | 0-5 cm | 16000 | <0.4 | 8.8 | 118 | 0.9 | 1.39 | 14000 | 26 | **61** | 242 | 20300 | 159 | 6300 | 397 | 3.5 | **1580** | <0.3 | 41 | 35 | 248 |
| | 5-10 cm | 16700 | <0.4 | 6.7 | 106 | 0.9 | 0.95 | 11200 | 22 | 40 | 156 | 20000 | 124 | 5570 | 351 | 3.2 | **1200** | <0.3 | 35 | 34 | 198 |
| | 10-20 cm | 18000 | <0.4 | 6.7 | 119 | 1.1 | 0.99 | 18800 | 23 | 32 | 124 | 20400 | 170 | 6710 | 361 | 3.6 | **976** | <0.3 | 50 | 36 | 224 |
| 2292322 (Back yard) | 0-5 cm | 17700 | <0.4 | 8.6 | 165 | 1.1 | 1.32 | 20600 | 25 | 33 | 152 | 22700 | **231** | 9120 | 382 | 3.8 | **1210** | <0.3 | 407 | 35 | 339 |
| | 5-10 cm | 19500 | <0.4 | 7.8 | 172 | **1.7** | 1.23 | 21200 | 27 | 33 | 154 | 26400 | **314** | 9310 | 438 | 3.8 | **1130** | <0.3 | 87 | 37 | 404 |
| | 10-20 cm | 19200 | <0.4 | 8.4 | 231 | 1.2 | 0.97 | 34700 | 27 | 26 | 119 | 24600 | **589** | 13000 | 484 | 4.3 | **974** | <0.3 | 97 | 36 | 588 |
| 2292323 (Front yard) | 0-5 cm | 19900 | <0.4 | 9.7 | 169 | 1.2 | 1.35 | 15300 | 30 | 38 | 211 | 26000 | 165 | 7020 | 578 | 3.6 | **1380** | <0.3 | 59 | 40 | 298 |
| | 0-5 cm | 19100 | <0.4 | 9.5 | 158 | 1.2 | 1.09 | 13100 | 28 | 37 | 196 | 24100 | 143 | 6560 | 484 | 3.8 | **1280** | <0.3 | 50 | 38 | 268 |
| | 0-5 cm | 21000 | <0.4 | 8.0 | 155 | 1.2 | 1.05 | 13500 | 30 | 35 | 179 | 26700 | 155 | 6700 | 588 | 3.9 | **1310** | <0.3 | 53 | 42 | 299 |
| | 5-10 cm | 19300 | <0.4 | 9.9 | 158 | 1.1 | 1.19 | 12900 | 27 | 39 | 217 | 25500 | 156 | 6360 | 494 | 3.6 | **1620** | <0.3 | 51 | 37 | 272 |
| | 5-10 cm | 19800 | <0.4 | 10.8 | 162 | 1.2 | 1.13 | 12300 | 30 | 39 | 219 | 27100 | 161 | 6410 | 517 | 3.7 | **1550** | <0.3 | 48 | 38 | 265 |
| | 5-10 cm | 21900 | <0.4 | 8.6 | 168 | 1.2 | 1.09 | 12500 | 30 | 39 | 218 | 27300 | 167 | 6410 | 517 | 3.6 | **1480** | <0.3 | 52 | 42 | 263 |
| | 10-20 cm | 17800 | <0.4 | 14.1 | 153 | 1.2 | 1.50 | 15900 | 26 | 38 | 245 | 29200 | 144 | 6420 | 633 | 3.5 | **1850** | <0.3 | 56 | 34 | 396 |
| | 10-20 cm | 20600 | <0.4 | 11.9 | 150 | 1.2 | 1.13 | 14100 | 29 | 40 | 236 | 27000 | 146 | 6600 | 559 | 3.4 | **1790** | <0.3 | 49 | 40 | 261 |
| | 10-20 cm | 19800 | <0.4 | 11.8 | 152 | 1.2 | 1.20 | 14000 | 27 | 39 | 223 | 29800 | 137 | 6340 | 697 | 3.6 | **1840** | <0.3 | 51 | 38 | 314 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292324 (Back yard) | 0-5 cm | 13600 | <0.4 | 13.2 | 185 | 1.1 | 2.07 | 14500 | 23 | 42 | 210 | 22900 | **256** | 5770 | 541 | 3.7 | **1820** | 0.30 | 78 | 31 | 394 |
| | 0-5 cm | 15100 | <0.4 | 1.3 | 188 | 1 | 1.45 | 13600 | 25 | 39 | 203 | 23600 | **224** | 5230 | 464 | 3.7 | **1920** | <0.3 | 69 | 33 | 364 |
| | 0-5 cm | 15700 | <0.4 | 14.4 | 194 | 1.2 | 1.84 | 15000 | 27 | 44 | 227 | 25500 | **263** | 5610 | 438 | 3.8 | **2060** | 0.50 | 76 | 35 | 384 |
| | 5-10 cm | 15700 | <0.4 | 15.5 | 216 | 1.2 | 2.12 | 17000 | 27 | 48 | 246 | 27800 | **276** | 6630 | 611 | 4.0 | **2340** | 0.60 | 89 | 33 | 446 |
| | 5-10 cm | 15900 | 0.4 | 13.8 | 211 | 1.1 | 1.57 | 15700 | 27 | 43 | 223 | 25900 | **266** | 6080 | 503 | 3.9 | **2230** | 0.50 | 77 | 35 | 418 |
| | 5-10 cm | 15900 | <0.4 | 18.4 | 219 | **1.3** | 2.37 | 17000 | 28 | 50 | 266 | 26800 | **344** | 6000 | 492 | 3.9 | **2650** | 0.60 | 87 | 35 | 424 |
| | 10-20 cm | 15600 | 1.0 | 20.0 | 266 | **1.8** | 1.78 | 21900 | 26 | 42 | 241 | 24400 | **263** | 6220 | 504 | 4.1 | **2320** | 0.30 | 170 | 34 | 433 |
| | 10-20 cm | 16700 | <0.4 | 17.8 | 207 | 1.2 | 1.58 | 19500 | 28 | 41 | 230 | 26400 | **260** | 6700 | 494 | 3.8 | **2360** | 0.70 | 92 | 35 | 412 |
| | 10-20 cm | 15500 | <0.4 | 16.0 | 224 | 1.2 | 1.72 | 22000 | 28 | 43 | 245 | 28000 | **237** | 6570 | 431 | 4.2 | **2400** | 0.80 | 109 | 35 | 391 |
| 2292325 (Front yard) | 0-5 cm | 13500 | <0.4 | 7.2 | 99 | 0.7 | 0.81 | 18900 | 20 | 25 | 120 | 16600 | 95 | 7760 | 321 | 4.0 | **894** | <0.3 | 59 | 30 | 158 |
| | 5-10 cm | 13500 | <0.4 | 7.9 | 94 | 0.7 | 0.83 | 13500 | 19 | 32 | 143 | 15800 | 104 | 5380 | 278 | 3.6 | **1070** | <0.3 | 46 | 29 | 163 |
| | 10-20 cm | 13100 | <0.4 | 9.8 | 92 | 0.7 | 0.87 | 12000 | 20 | 38 | 184 | 17800 | 88 | 4780 | 293 | 3.7 | **1700** | <0.3 | 40 | 27 | 183 |
| 2292326 (Back yard) | 0-5 cm | 11300 | <0.4 | 10.4 | 111 | 0.6 | 1.18 | 16000 | 23 | 28 | 160 | 16000 | 148 | 6380 | 269 | 3.8 | **939** | <0.3 | 43 | 24 | 294 |
| | 5-10 cm | 10400 | <0.4 | 10.0 | 109 | 0.6 | 1.11 | 13500 | 19 | 28 | 158 | 16100 | 143 | 5740 | 246 | 3.6 | **1130** | <0.3 | 43 | 23 | 315 |
| | 10-20 cm | 11900 | <0.4 | 11.2 | 141 | 0.7 | 0.94 | 15000 | 20 | 31 | 242 | 16700 | 173 | 5890 | 244 | 3.6 | **1170** | <0.3 | 49 | 24 | 329 |
| 2292327 (Front yard) | 0-5 cm | 28200 | <0.4 | 12.1 | 218 | **1.3** | 1.63 | 20700 | 37 | **72** | **303** | 28900 | **210** | 10500 | 453 | 4.8 | **3340** | <0.3 | 64 | 52 | 351 |
| | 5-10 cm | 29500 | <0.4 | 15.0 | 234 | **1.3** | 2.03 | 27100 | 42 | **96** | **438** | 32100 | **216** | 12200 | 497 | 4.7 | **4710** | 0.45 | 69 | 54 | 432 |
| | 10-20 cm* | 20200 | 0.6 | 21.2 | 183 | 1 | 0.90 | 47625 | 31 | **76** | **416** | 33100 | 175 | 18675 | 590 | 3.2 | **5785** | 2.58 | 83 | 39 | 331 |
| 2292328 (Back yard) | 0-5 cm | 26900 | <0.4 | 12.2 | 192 | **1.3** | 1.76 | 30200 | 33 | **61** | 266 | 32700 | **212** | 11700 | 724 | 4.8 | **2820** | <0.3 | 73 | 48 | 331 |
| | 5-10 cm | 26100 | <0.4 | 9.4 | 161 | 1.2 | 1.28 | 35500 | 31 | 48 | 207 | 29700 | 133 | 15600 | 604 | 5.0 | **2280** | <0.3 | 70 | 46 | 255 |
| | 10-20 cm | 21500 | <0.4 | 9.5 | 141 | 1 | 0.77 | 51700 | 27 | 32 | 155 | 26100 | 94 | 21200 | 550 | 5.0 | **1820** | <0.3 | 81 | 39 | 175 |
| 2292329 (Front yard) | 0-5 cm | 24600 | <0.4 | 13.7 | 203 | **1.3** | 1.85 | 21200 | 36 | **71** | 292 | 28800 | **261** | 9280 | 596 | 4.8 | **3310** | <0.3 | 73 | 52 | 430 |
| | 5-10 cm | 25200 | <0.4 | 14 | 205 | 1 | 1.90 | 21200 | 36 | **82** | 344 | 30500 | **228** | 9270 | 596 | 5 | **4120** | 1 | 75 | 53 | 406 |
| | 10-20 cm* | 25025 | 0.5 | 17.5 | 208 | 1.2 | 1.21 | 17725 | 35 | **71** | 328 | 30450 | 199 | 8538 | 709 | 2.7 | **3593** | 1.41 | 65 | 51 | 344 |
| 2292330 (Back yard) | 0-5 cm | 25900 | <0.4 | 8.6 | 162 | **1.3** | 0.90 | 17900 | 32 | 35 | 136 | 27800 | 109 | 8120 | 459 | 4.4 | **1440** | <0.3 | 69 | 48 | 213 |
| | 5-10 cm | 31100 | <0.4 | 8.2 | 182 | **1.6** | 0.87 | 32700 | 36 | 35 | 128 | 32700 | 93 | 10000 | 538 | 4.6 | **1310** | <0.3 | 81 | 55 | 192 |
| | 10-20 cm* | 20400 | 0.5 | 13.8 | 143 | 1.1 | 0.79 | 15425 | 28 | 42 | 196 | 25700 | 99 | 5823 | 444 | 2.6 | **2088** | 1.18 | 71 | 43 | 218 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292331 (Side yard) | 0-5 cm | 23800 | <0.4 | 13.0 | 119 | 1.1 | 1.04 | 24400 | 34 | **67** | 243 | 30000 | 169 | 9020 | 774 | 4.7 | **2880** | <0.3 | 36 | 49 | 270 |
| | 5-10 cm | 26600 | <0.4 | 12 | 138 | 1 | 0.90 | 49500 | 34 | 49 | 188 | 29900 | **337** | 9310 | 744 | 5 | **2100** | <0.3 | 43 | 51 | 245 |
| | 10-20 cm | 25700 | <0.4 | 9.0 | 109 | 1.1 | 0.58 | 80100 | 28 | 23 | 63 | 25200 | 73 | 8080 | 682 | 5.3 | **624** | 0.34 | 49 | 46 | 111 |
| 2292332 (Back yard) | 0-5 cm | 19400 | <0.4 | 8.7 | 122 | 0.8 | 0.83 | 14600 | 28 | 27 | 107 | 19300 | 91 | 7490 | 386 | 4.0 | **1130** | <0.3 | 49 | 35 | 194 |
| | 5-10 cm* | 19400 | 0.5 | 10.9 | 124 | 0.8 | 0.74 | 15325 | 28 | 29 | 127 | 18375 | 94 | 7445 | 355 | 2.4 | **1248** | 0.60 | 53 | 36 | 212 |
| | 10-20 cm* | 16050 | 0.5 | 13.8 | 121 | 0.8 | 0.77 | 33750 | 24 | 32 | 156 | 17275 | 123 | 17425 | 323 | 3.0 | **1616** | 0.70 | 83 | 31 | 243 |
| 2292333 (Front yard) | 0-5 cm | 18700 | <0.4 | 13.1 | 141 | 0.9 | 1.44 | 12600 | 32 | **70** | **306** | 26500 | **261** | 6760 | 619 | 4.1 | **3320** | 1.00 | 42 | 40 | 412 |
| | 5-10 cm* | 16700 | 0.6 | 16.4 | 131 | 0.8 | 0.99 | 12200 | 29 | **66** | **318** | 25800 | **246** | 6555 | 605 | 2.5 | **3650** | 1.48 | 37 | 38 | 380 |
| | 10-20 cm* | 16275 | 0.5 | 18.2 | 135 | 0.8 | 0.91 | 13075 | 27 | **58** | **316** | 26175 | **234** | 6495 | 612 | 2.3 | **3693** | 2.35 | 38 | 36 | 341 |
| 2292334 (Back yard) | 0-5 cm* | 16475 | 0.4 | 11.0 | 104 | 0.7 | 0.69 | 9180 | 24 | 35 | 149 | 19875 | 90 | 4635 | 315 | 2.2 | **1620** | 0.65 | 36 | 34 | 215 |
| | 5-10 cm | 18500 | <0.4 | 9 | 101 | 1 | 0.78 | 9600 | 23 | 32 | 132 | 21700 | 78 | 4950 | 340 | 4 | **1830** | <0.3 | 36 | 37 | 183 |
| | 10-20 cm* | 17125 | 0 | 14 | 112 | 1 | 0.66 | 13125 | 24 | 32 | 173 | 20775 | 89 | 5543 | 326 | 2 | **1703** | 1 | 46 | 35 | 214 |
| 2292335 (Front yard) | 0-5 cm | 21300 | <0.4 | 8.6 | 125 | 0.9 | 0.99 | 12100 | 32 | **64** | 208 | 22700 | 179 | 6160 | 427 | 4.1 | **2140** | <0.3 | 44 | 42 | 267 |
| | 5-10 cm | 21100 | <0.4 | 8.4 | 123 | 0.9 | 0.98 | 13300 | 30 | **76** | 237 | 23600 | 172 | 6640 | 439 | 4.1 | **2600** | <0.3 | 43 | 42 | 273 |
| | 10-20 cm* | 20550 | 0.5 | 22.3 | 121 | 1 | 0.85 | 10363 | 32 | **100** | 441 | 29425 | 164 | 5645 | 500 | 2.5 | **5913** | 3.15 | 42 | 41 | 307 |
| 2292336 (Back yard) | 0-5 cm* | 13100 | 0.4 | 11.3 | 102 | 0.6 | 1.27 | 13400 | 43 | **66** | 239 | 21775 | 170 | 5835 | 416 | 2.6 | **2698** | 2.23 | 45 | 34 | 349 |
| | 5-10 cm | 15800 | <0.4 | 13 | 104 | 1 | 1.55 | 12000 | 31 | **89** | **376** | 36400 | 171 | 5660 | 482 | 4 | **4670** | 3 | 43 | 36 | 430 |
| | 10-20 cm* | 13600 | 0.3 | 6.2 | 75 | 0.5 | 0.50 | 30010 | 19 | 21 | 90 | 21475 | 55 | 4580 | 325 | 1.9 | **1166** | 0.56 | 30 | 36 | 142 |
| 2292337 (Front yard) | 0-5 cm | 21200 | <0.4 | 18.6 | 157 | 1.1 | 1.60 | 11900 | 34 | **112** | **384** | 28800 | **208** | 6850 | 615 | 4.0 | **4680** | 1.56 | 39 | 48 | 401 |
| | 5-10 cm | 18000 | <0.4 | 14 | 116 | 1 | 1.10 | 9130 | 27 | **57** | 242 | 26900 | 101 | 6260 | 636 | 4 | **3090** | 0 | 28 | 42 | 227 |
| | 10-20 cm* | 17650 | 0.4 | 14.4 | 104 | 0.8 | 0.58 | 9745 | 27 | 48 | 231 | 25125 | 86 | 5995 | 569 | 2.2 | **3133** | 1.58 | 28 | 39 | 204 |
| 2292338 (Back yard) | 0-5 cm | 22700 | <0.4 | 12.5 | 186 | 1.1 | 1.26 | 11100 | 33 | **55** | 249 | 28200 | 153 | 5770 | 555 | 4.1 | **2820** | 0.30 | 53 | 47 | 328 |
| | 5-10 cm | 18500 | <0.4 | 12 | 138 | 1 | 0.92 | 9200 | 26 | 40 | 178 | 21700 | 95 | 4780 | 485 | 4 | **2000** | <0.3 | 43 | 37 | 230 |
| | 10-20 cm* | 18800 | 0.4 | 14.9 | 168 | 1 | 0.67 | 11058 | 28 | 45 | 226 | 23625 | 112 | 5068 | 434 | 2.3 | **2698** | 0.92 | 49 | 40 | 250 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292339 (Front yard) | 0-5 cm | 24700 | <0.4 | 16.5 | 339 | 1.2 | 1.46 | 14000 | 36 | **99** | **346** | 26700 | **426** | 7590 | 474 | 0.8 | **3390** | 0.40 | 56 | 52 | 694 |
|  | 0-5 cm | 22800 | 0.5 | 21.4 | 348 | 1.2 | 1.68 | 14400 | 36 | **152** | **497** | 25700 | **431** | 7610 | 464 | 0.9 | **4730** | 1.51 | 58 | 50 | 717 |
|  | 0-5 cm | 23900 | <0.4 | 17 | 356 | 1 | 1.38 | 12600 | 34 | **114** | **380** | 26000 | **465** | 7240 | 490 | 1 | **3650** | 1 | 53 | 50 | 661 |
|  | 5-10 cm | 29900 | 1 | 31 | 326 | 1 | 2.07 | 16000 | 43 | **222** | **694** | 32800 | **362** | 8870 | 494 | 1 | **7000** | 2 | 66 | 59 | 697 |
|  | 5-10 cm | 28000 | 1 | 27 | 250 | 1 | 1.55 | 15900 | 38 | **188** | **616** | 30300 | **261** | 8740 | 493 | 1 | **6330** | 1 | 62 | 56 | 523 |
|  | 5-10 cm | 28600 | <0.4 | 24.4 | 305 | **1.4** | 1.63 | 14500 | 42 | **179** | **561** | 29500 | **312** | 8070 | 491 | 0.8 | **6610** | 0.88 | 63 | 55 | 553 |
|  | 10-20 cm* | 28675 | 1.1 | **30.2** | 243 | **1.4** | 1.28 | 17650 | 42 | **162** | **654** | 32275 | **224** | 8638 | 464 | 2.0 | **7540** | 3.58 | 68 | 54 | 600 |
|  | 10-20 cm* | 25800 | 1.2 | **36.9** | 269 | **1.3** | 1.19 | 17225 | 45 | **214** | **871** | 35200 | **282** | 8295 | 500 | 2.1 | **9025** | 5.83 | 69 | 52 | **914** |
|  | 10-20 cm | 28075 | 1.1 | **31.2** | 243 | **1.4** | 1.24 | 19500 | 45 | **174** | **718** | 33825 | **249** | 8930 | 486 | 2.1 | **8363** | 3.65 | 69 | 53 | 605 |
| 2292340 (Back yard) | 0-5 cm | 15700 | <0.4 | **26.5** | 143 | 0.9 | 1.12 | 15000 | 25 | 31 | 165 | 20700 | 184 | 5840 | 466 | 0.4 | **1230** | <0.3 | 62 | 37 | 273 |
|  | 0-5 cm* | 13475 | 0.3 | 12.4 | 97 | 0.7 | 0.58 | 10048 | 21 | 24 | 116 | 19175 | 76 | 4945 | 516 | 1.2 | **935** | 0.65 | 41 | 32 | 211 |
|  | 0-5 cm* | 11700 | 0.4 | 11.6 | 101 | 0.7 | 0.60 | 12250 | 19 | 26 | 148 | 18425 | 113 | 4860 | 441 | 1.3 | **867** | 0.69 | 46 | 30 | 231 |
|  | 5-10 cm* | 15075 | 0.5 | **32.5** | 120 | 0.8 | 0.78 | 15525 | 24 | 32 | 175 | 21150 | 184 | 5828 | 473 | 1.3 | **1480** | 0.58 | 52 | 36 | 227 |
|  | 5-10 cm* | 11375 | <0.47 | 7.8 | 62 | 0.5 | 0.34 | 8195 | 15 | 16 | 63 | 17700 | 39 | 4250 | 568 | 1.0 | **486** | 0.45 | 28 | 27 | 104 |
|  | 5-10 cm* | 11750 | 0 | 11 | 79 | 1 | 0.54 | 12500 | 17 | 23 | 110 | 18325 | 78 | 4883 | 519 | 1 | **865** | 1 | 39 | 29 | 169 |
|  | 10-20 cm* | 13825 | 0.4 | **27.5** | 128 | 0.9 | 0.69 | 14325 | 23 | 32 | 180 | 19725 | 156 | 5323 | 426 | 1.3 | **1665** | 0.50 | 61 | 34 | 235 |
|  | 10-20 cm* | 12950 | 0.4 | 17.5 | 115 | 0.8 | 0.69 | 12925 | 20 | 31 | 167 | 19525 | 96 | 4938 | 476 | 1.2 | **1426** | 0.60 | 56 | 32 | 220 |
|  | 10-20 cm* | 11375 | 0.4 | 15.8 | 117 | 0.7 | 0.70 | 14000 | 19 | 35 | 221 | 19050 | 152 | 4745 | 428 | 1.0 | **1680** | 0.63 | 53 | 30 | 261 |
| 2292341 (Front yard) | 0-5 cm | 25600 | <0.4 | 23.2 | 235 | **1.7** | 2.45 | 19400 | 38 | **66** | **320** | 26900 | **244** | 8540 | 489 | 5.4 | **2970** | 6.30 | 77 | 53 | 422 |
|  | 5-10 cm | 28700 | <0.4 | 16 | 205 | **2** | 1.52 | 29600 | 37 | 49 | 208 | 31500 | 153 | 12800 | 613 | 6 | **2060** | 0 | 77 | 56 | 294 |
|  | 10-20 cm* | 24500 | 0.6 | **44.3** | 227 | **1.4** | 2.42 | 24575 | 38 | **100** | **566** | 36400 | **321** | 9285 | 777 | 2.9 | **6733** | 2.65 | 77 | 46 | 546 |
| 2292342 (Back yard) | 0-5 cm | 26100 | <0.4 | **31.8** | 261 | **1.6** | 2.37 | 17700 | 40 | **64** | **372** | 25700 | **283** | 7300 | 401 | 5.1 | **3110** | 1.20 | 90 | 54 | 434 |
|  | 5-10 cm | 23500 | <0.4 | **44** | 253 | **2** | 2.83 | 18100 | 39 | **69** | **392** | 25200 | **315** | 7290 | 390 | 5 | **3710** | 1 | 92 | 51 | 479 |
|  | 10-20 cm* | 22850 | 0.8 | **47.6** | 287 | **1.4** | 1.97 | 19275 | 38 | **67** | **433** | 27400 | **367** | 6773 | 281 | 2.6 | **4570** | 1.68 | 102 | 46 | 525 |
| 2292343 (Front yard) | 0-5 cm | 17900 | <0.4 | 18.8 | 282 | **1.4** | 2.16 | 27100 | 37 | **107** | **469** | 29900 | **622** | 10300 | 589 | 6.3 | **5230** | 2.40 | 92 | 44 | 618 |
|  | 5-10 cm | 16700 | <0.4 | **32.1** | 288 | **1.6** | 2.44 | 32000 | 35 | **116** | **621** | 34600 | **596** | 10400 | 704 | 6.5 | **7740** | <0.3 | 109 | 36 | 638 |
|  | 10-20 cm* | 18700 | 0.8 | **25.3** | 277 | **1.4** | 1.30 | 32400 | 33 | **60** | **423** | 30600 | **511** | 7990 | 635 | 2.7 | **5670** | 1.84 | 123 | 37 | 472 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292344 (Back yard) | 0-5 cm | 23300 | <0.4 | 13.5 | 188 | **1.4** | 1.44 | 16700 | 33 | 43 | 220 | 24900 | 159 | 6880 | 432 | 5.5 | **2080** | 0.50 | 80 | 48 | 325 |
| | 5-10 cm | 23400 | <0.4 | 14.1 | 186 | **1.4** | 1.47 | 16300 | 33 | 47 | 236 | 25900 | 176 | 6900 | 431 | 5.3 | **2330** | <0.3 | 80 | 48 | 331 |
| | 10-20 cm | 25100 | <0.4 | 17.0 | 200 | **1.5** | 1.58 | 18000 | 36 | 50 | 265 | 26900 | 177 | 7410 | 434 | 5.3 | **2580** | <0.3 | 87 | 51 | 334 |
| 2292345 (Front yard) | 0-5 cm | 20200 | <0.4 | 14.5 | 179 | **1.4** | 1.59 | 30800 | 32 | **58** | 288 | 27900 | 179 | 12000 | 612 | 5.7 | **2770** | 0.40 | 82 | 43 | 387 |
| | 5-10 cm | 24200 | <0.4 | 21 | 209 | **2** | 1.86 | 30600 | 36 | **74** | **406** | 36400 | 185 | 12500 | 985 | 6 | **4380** | 1 | 79 | 47 | 438 |
| | 10-20 cm* | 24325 | 1 | 22 | 270 | **2** | 2.04 | 38000 | 35 | **52** | **311** | 48400 | **211** | 11425 | 1648 | 3 | **3620** | 2 | 112 | 44 | 699 |
| 2292346 (Front yard) | 0-5 cm | 17000 | 9.2 | 6.3 | 160 | 1.1 | 1.83 | 34400 | 32 | 40 | 142 | 21600 | 169 | 15300 | 819 | 6.2 | **999** | <0.3 | 117 | 42 | 402 |
| | 5-10 cm | 18900 | 9.3 | 8.0 | 177 | **1.3** | 2.45 | 36200 | 32 | 47 | 166 | 26100 | **217** | 13700 | 1540 | 6.0 | **1240** | <0.3 | 139 | 44 | 610 |
| 2292347 (Front yard) | 0-5 cm | 17700 | 6.9 | 10.8 | 152 | 1 | 1.55 | 24600 | 33 | **65** | 272 | 25900 | 196 | 9980 | 489 | 5.7 | **2660** | <0.3 | 76 | 41 | 374 |
| | 5-10 cm | 19500 | 8 | 14 | 170 | 1 | 1.74 | 23300 | 33 | **64** | **314** | 28000 | **260** | 9790 | 479 | 6 | **3070** | <0.3 | 78 | 43 | 395 |
| | 10-20 cm* | 18550 | 3 | 16 | 163 | 1 | 1.55 | 24075 | 31 | **63** | 274 | 26550 | 184 | 9155 | 475 | 3 | **2656** | 1 | 73 | 39 | 333 |
| 2292348 (Back yard) | 0-5 cm | 23100 | 7.2 | 11.0 | 194 | 1.2 | 2.90 | 24500 | 48 | **66** | **318** | 27200 | **241** | 12600 | 457 | 5.8 | **2820** | <0.3 | 69 | 49 | 536 |
| | 5-10 cm | 26700 | 7.7 | 14.9 | 210 | **1.4** | 3.31 | 22000 | 48 | **84** | **389** | 30900 | **267** | 11000 | 480 | 5.7 | **3680** | <0.3 | 65 | 53 | 631 |
| | 10-20 cm* | 24700 | 2.9 | 16.8 | 189 | **1.3** | 2.14 | 26650 | 40 | **66** | 300 | 30375 | 164 | 11575 | 445 | 3.3 | **2963** | 1.35 | 75 | 48 | 405 |
| 2292349 (Back yard) | 0-5 cm* | 16200 | 1.9 | 7.1 | 156 | 0.8 | 1.22 | 22050 | 25 | 24 | 134 | 20925 | 134 | 7238 | 409 | 3.0 | **869** | 0.65 | 106 | 3227 | |
| | 5-10 cm | 21900 | 8 | 8 | 201 | 1 | 1.40 | 23300 | 33 | 33 | 178 | 25700 | 189 | 7800 | 456 | 5 | **1110** | <0.3 | 136 | 40 | 351 |
| | 10-20 cm* | 21200 | 3 | 12 | 312 | 1 | 1.82 | 30500 | 34 | 44 | **346** | 28450 | **270** | 8108 | 437 | 3 | **1960** | 1 | 179 | 39 | 509 |
| 2292350 (Front yard) | 0-5 cm* | 17375 | 1.3 | 6.2 | 96 | 0.7 | 0.77 | 7375 | 25 | 25 | 89 | 19750 | 87 | 4893 | 430 | 2.5 | **832** | 0.63 | 28 | 36 | 154 |
| | 5-10 cm* | 16750 | 1.3 | 5.6 | 89 | 0.7 | 0.71 | 6853 | 23 | 25 | 89 | 19450 | 77 | 4525 | 428 | 2.4 | **811** | 0.58 | 25 | 35 | 133 |
| | 10-20 cm* | 17325 | 1.0 | 8.6 | 98 | 0.7 | 0.84 | 7020 | 24 | 36 | 148 | 22075 | 92 | 4890 | 474 | 2.3 | **1466** | 0.80 | 25 | 36 | 162 |
| 2292351 (Back yard) | 0-5 cm* | 18250 | 1.9 | 9.6 | 157 | 1 | 0.97 | 14525 | 31 | 31 | 124 | 23000 | 167 | 8130 | 446 | 2.9 | **1286** | 0.68 | 57 | 40 | 232 |
| | 5-10 cm* | 21250 | 2 | 10 | 162 | 1 | 0.98 | 14800 | 32 | 33 | 134 | 25775 | 198 | 8368 | 478 | 3 | **1328** | 1 | 63 | 42 | 234 |
| | 10-20 cm* | 21450 | 2.2 | 10.0 | 162 | 1 | 0.85 | 16375 | 30 | 32 | 126 | 26150 | 196 | 8383 | 476 | 3.0 | **1276** | 0.68 | 65 | 42 | 215 |
| 2292352 (Back yard) | 0-5 cm | 19300 | 0.8 | 12.7 | 128 | 0.8 | 1.25 | 14000 | 38 | **64** | **455** | 25100 | 164 | 6360 | 591 | 1.1 | **2300** | <0.3 | 45 | 44 | 343 |
| | 5-10 cm | 19500 | 0.8 | 14.4 | 123 | 0.9 | 1.13 | 13200 | 29 | **69** | **569** | 25800 | 122 | 6310 | 624 | 0.8 | **2570** | 0.90 | 44 | 44 | 316 |
| | 10-20 cm | 21600 | <0.4 | 13.2 | 120 | 0.9 | 0.98 | 11900 | 33 | **54** | **516** | 26700 | 100 | 6360 | 612 | 0.8 | **2040** | <0.3 | 45 | 47 | 284 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292353 (Front yard) | 0-5 cm | 10400 | 3.2 | 13.5 | 166 | 0.5 | 2.33 | 66300 | 30 | **77** | 299 | 29400 | **562** | 31900 | 478 | 2.3 | **2590** | 0.70 | 104 | 27 | 721 |
| 2292354 (Front yard) | 0-5 cm | 18900 | 0.7 | 12.1 | 137 | 0.8 | 1.01 | 10800 | 31 | **118** | **342** | 26000 | 123 | 6180 | 553 | 0.9 | **3900** | 1.50 | 54 | 46 | 290 |
|  | 5-10 cm | 22600 | <0.4 | 13.0 | 131 | 1 | 0.93 | 8720 | 29 | **92** | **303** | 27300 | 86 | 6200 | 537 | 0.7 | **3190** | <0.3 | 56 | 50 | 225 |
|  | 10-20 cm | 14300 | <0.4 | 7.2 | 64 | 0.5 | 0.40 | 3550 | 21 | 32 | 120 | 21000 | 30 | 3470 | 564 | 0.2 | **1420** | <0.3 | 24 | 36 | 131 |
| 2292355 (Front yard) | 0-5 cm | 13500 | <0.4 | 8.3 | 61 | 0.4 | 0.52 | 6690 | 17 | **51** | 148 | 21900 | 63 | 3300 | 328 | 0.5 | **2150** | <0.3 | 22 | 33 | 164 |
|  | 5-10 cm | 15400 | <0.4 | 5.4 | 48 | 0.4 | 0.36 | 4910 | 17 | 30 | 85 | 17100 | 34 | 2980 | 269 | 0.5 | **974** | <0.3 | 16 | 34 | 92 |
|  | 10-20 cm | 15200 | 1.7 | **43.0** | 162 | 1 | 2.04 | 15800 | 32 | **167** | **792** | 59700 | **333** | 6200 | 627 | 2.0 | **12000** | 6.10 | 56 | 43 | 743 |
| 2292356 (Back yard) | 0-5 cm | 16100 | 0.4 | 12.7 | 176 | 0.8 | 1.15 | 10200 | 29 | 46 | 193 | 22600 | 166 | 3750 | 319 | 0.9 | **2070** | 0.40 | 54 | 38 | 350 |
|  | 5-10 cm | 19700 | 1.0 | 18.8 | 290 | **1.4** | 1.87 | 9100 | 34 | **60** | 284 | 28800 | **282** | 3730 | 343 | 1.7 | **3100** | 0.40 | 101 | 44 | 542 |
|  | 10-20 cm | 23300 | 5.3 | **38.6** | 569 | **2.4** | 2.30 | 15100 | 53 | **87** | **619** | 42600 | **540** | 4440 | 477 | 2.8 | **6300** | 2.20 | 219 | 55 | **923** |
| 2292357 (Front yard) | 0-5 cm | 14100 | 1.1 | **28.5** | 212 | 0.7 | 1.77 | 26400 | 47 | **143** | **581** | 34800 | **327** | 10800 | 577 | 1.5 | **6770** | 4.30 | 59 | 39 | 467 |
|  | 5-10 cm | 12600 | 1.1 | **36.7** | 161 | 0.7 | 2.13 | 30900 | 35 | **163** | **775** | 49000 | **296** | 10400 | 646 | 1.7 | **10600** | 5.80 | 63 | 38 | 568 |
|  | 10-20 cm | 15500 | 2.3 | **33.9** | 259 | 0.9 | 2.21 | 32000 | 34 | **111** | **751** | 41700 | **329** | 9680 | 665 | 1.2 | **9300** | 4.50 | 86 | 40 | **888** |
| 2292358 (Back yard) | 0-5 cm | 16300 | 1.0 | 24.1 | 178 | 1 | 1.47 | 12900 | 28 | **83** | **407** | 38800 | **212** | 5820 | 472 | 1.0 | **5300** | 3.60 | 59 | 49 | 565 |
|  | 0-5 cm | 16200 | 1.2 | **26.1** | 206 | 0.9 | 1.73 | 13300 | 28 | **87** | **437** | 40600 | **257** | 5710 | 496 | 0.9 | **6010** | 3.80 | 63 | 48 | 654 |
|  | 0-5 cm | 15100 | 0.5 | 20.4 | 152 | 0.7 | 1.19 | 12400 | 25 | **73** | **349** | 30100 | 176 | 5430 | 407 | 0.8 | **4660** | 1.30 | 50 | 40 | 406 |
|  | 5-10 cm | 18500 | 1.8 | **36.3** | 212 | 1.2 | 1.77 | 16500 | 31 | **78** | **460** | 49400 | 221 | 6300 | 519 | 1.3 | **6470** | 2.40 | 79 | 56 | 754 |
|  | 5-10 cm | 15800 | 1.5 | **31.3** | 191 | 1.2 | 1.72 | 16000 | 26 | **67** | **393** | 58100 | 195 | 5550 | 553 | 1.5 | **4740** | 1.10 | 89 | 62 | **944** |
|  | 5-10 cm | 17500 | 0.7 | **29.8** | 192 | 0.9 | 1.33 | 15400 | 31 | **84** | **457** | 36800 | **249** | 6280 | 482 | 0.7 | **6250** | 0.80 | 60 | 44 | 511 |
|  | 10-20 cm | 17100 | 1.3 | **27.7** | 224 | 1.1 | 1.38 | 17800 | 26 | **57** | **366** | 43900 | **206** | 6000 | 464 | 1.0 | **4110** | 1.20 | 78 | 52 | 637 |
|  | 10-20 cm | 16800 | 0.9 | **27.3** | 175 | 1 | 1.28 | 17200 | 30 | **63** | **355** | 39100 | 168 | 5840 | 448 | 0.9 | **4390** | 1.50 | 74 | 48 | 572 |
|  | 10-20 cm | 18000 | 0.5 | **30.7** | 197 | 0.9 | 1.41 | 17600 | 33 | **78** | **455** | 37100 | **237** | 6470 | 455 | 0.8 | **5820** | 0.80 | 67 | 44 | 529 |
| 2292359 (Front yard) | 0-5 cm | 18200 | <0.4 | 3.6 | 95 | 0.6 | 0.25 | 14600 | 22 | 13 | 31 | 19000 | 23 | 6570 | 422 | 0.3 | 162 | <0.3 | 48 | 42 | 74 |
|  | 5-10 cm | 18800 | <0.4 | 4.0 | 95 | 0.6 | 0.29 | 13300 | 32 | 12 | 29 | 20100 | 22 | 6100 | 472 | 0.3 | 117 | <0.3 | 46 | 43 | 73 |
|  | 10-20 cm | 19600 | <0.4 | 5.6 | 108 | 0.7 | 0.34 | 20900 | 24 | 18 | 68 | 23600 | 47 | 9150 | 495 | 0.5 | **632** | <0.3 | 62 | 45 | 101 |
| 2292360 (Back yard) | 0-5 cm | 20800 | <0.4 | 7.7 | 169 | 0.8 | 0.62 | 27100 | 25 | 25 | 116 | 25700 | 117 | 9670 | 518 | 0.5 | **1000** | <0.3 | 67 | 44 | 175 |
|  | 5-10 cm | 32800 | <0.4 | 11.3 | 224 | **1.3** | 0.62 | 38900 | 35 | 35 | 152 | 42800 | 117 | 14800 | 722 | 0.7 | **1650** | <0.3 | 90 | 63 | 238 |
|  | 10-20 cm | 32500 | 0.7 | 23.4 | 377 | **1.4** | 1.18 | 25600 | 43 | **77** | **390** | 48500 | **292** | 12500 | 599 | 1.2 | **5210** | 0.70 | 88 | 67 | 491 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292361 (Front yard) | 0-5 cm | 20300 | <0.4 | 5.6 | 121 | 0.7 | 0.42 | 20500 | 24 | 21 | 73 | 21300 | 37 | 9660 | 478 | 0.6 | **528** | <0.3 | 73 | 44 | 111 |
| | 5-10 cm | 23400 | <0.4 | 6.8 | 148 | 0.8 | 0.45 | 31700 | 28 | 28 | 118 | 27100 | 64 | 14500 | 571 | 0.8 | **1190** | <0.3 | 82 | 49 | 166 |
| | 10-20 cm | 28400 | <0.4 | 10.3 | 199 | 1.1 | 0.63 | 38800 | 34 | **56** | 231 | 32700 | 99 | 16900 | 541 | 1.1 | **2640** | <0.3 | 90 | 58 | 200 |
| 2292362 (Back yard) | 0-5 cm | 24400 | <0.4 | 7.0 | 159 | 0.9 | 0.38 | 26400 | 28 | 24 | 98 | 26400 | 85 | 11400 | 415 | 0.5 | **964** | <0.3 | 65 | 50 | 155 |
| | 5-10 cm | 35800 | <0.4 | 9.9 | 242 | **1.4** | 0.47 | 34500 | 40 | 31 | 131 | 39600 | 111 | 15300 | 620 | 0.8 | **1300** | <0.3 | 88 | 68 | 197 |
| | 10-20 cm | 34900 | <0.4 | 9.3 | 232 | **1.4** | 0.40 | 38100 | 37 | 31 | 150 | 36900 | 106 | 14900 | 561 | 0.7 | **1320** | <0.3 | 95 | 66 | 197 |
| 2292363 (Front yard) | 0-5 cm | 15300 | <0.4 | 3.7 | 102 | 0.5 | 0.42 | 13700 | 20 | 11 | 41 | 16800 | 19 | 5770 | 432 | 0.4 | 161 | <0.3 | 51 | 34 | 80 |
| | 5-10 cm | 21400 | <0.4 | 5.7 | 158 | 0.7 | 0.49 | 19100 | 27 | 17 | 67 | 22900 | 39 | 9390 | 518 | 0.7 | **464** | <0.3 | 77 | 46 | 113 |
| | 10-20 cm | 29600 | <0.4 | 7.5 | 203 | 1.1 | 0.56 | 34600 | 36 | 28 | 132 | 30600 | 78 | 16900 | 593 | 0.8 | **1120** | <0.3 | 119 | 58 | 147 |
| 2292364 (Back yard) | 0-5 cm | 28000 | 0.5 | 9.8 | 214 | 1.1 | 0.72 | 29100 | 34 | 32 | 176 | 32100 | 154 | 12200 | 481 | 0.6 | **1360** | <0.3 | 80 | 55 | 241 |
| | 5-10 cm | 32000 | <0.4 | 10.2 | 227 | **1.3** | 0.47 | 37600 | 35 | 31 | 146 | 35600 | 136 | 14900 | 519 | 0.6 | **1530** | <0.3 | 91 | 62 | 209 |
| | 10-20 cm | 31800 | <0.4 | 11.9 | 272 | **1.3** | 0.56 | 39200 | 36 | 46 | 217 | 37000 | **254** | 15600 | 557 | 0.8 | **2120** | <0.3 | 101 | 63 | 251 |
| 2292365 (Back yard) | 0-5 cm | 16000 | 5.3 | **33.2** | 447 | **1.5** | 5.08 | 33000 | 45 | **175** | **720** | 43400 | **1130** | 8140 | 819 | 2.2 | **6930** | 8.70 | 129 | 48 | **1590** |
| | 5-10 cm | 20000 | 6.0 | **47.7** | 557 | **2.2** | 4.19 | 43500 | 47 | **177** | **977** | 72100 | **1290** | 7700 | 954 | 2.9 | **12100** | 6.30 | 192 | 46 | **1440** |
| | 10-20 cm | 33100 | <0.4 | **32.3** | 579 | **4.6** | 4.35 | 93400 | 50 | **88** | **917** | 47600 | **877** | 7390 | 1440 | 6.7 | **8680** | 1.30 | 393 | 33 | **1390** |
| 2292366 (Front yard) | 0-5 cm | 19400 | <0.4 | 23.4 | 160 | 0.7 | 1.69 | 16400 | 40 | **115** | **462** | 43200 | **213** | 8830 | 669 | 5.2 | **6870** | 3.40 | 56 | 42 | 587 |
| | 5-10 cm | 22200 | <0.4 | **41.2** | 193 | 0.8 | 2.41 | 15200 | 48 | **147** | **671** | 57400 | **245** | 8460 | 804 | 5.9 | **10600** | 6.60 | 51 | 43 | **836** |
| | 10-20 cm | 24400 | <0.4 | 24.2 | 171 | 0.9 | 1.57 | 15100 | 40 | **78** | **384** | 39500 | 157 | 8620 | 654 | 4.8 | **5380** | 3.00 | 52 | 48 | 463 |
| 2292367 (Back yard) | 0-5 cm | 22400 | <0.4 | **26.7** | 190 | 0.9 | 1.78 | 13800 | 37 | **81** | **367** | 35500 | **207** | 6480 | 671 | 4.4 | **4240** | 1.80 | 68 | 46 | 441 |
| | 5-10 cm | 21200 | <0.4 | **30.0** | 178 | 0.9 | 1.60 | 10500 | 36 | **68** | **336** | 36300 | 168 | 5950 | 606 | 4.4 | **4610** | 1.00 | 61 | 43 | 392 |
| | 10-20 cm | 22700 | <0.4 | **33.4** | 198 | 1 | 1.68 | 13200 | 38 | **58** | **319** | 36600 | 189 | 6420 | 582 | 4.7 | **4180** | 0.70 | 75 | 45 | 381 |
| 2292368 (Front yard) | 0-5 cm | 17300 | <0.4 | 8.3 | 109 | 0.6 | 0.83 | 15200 | 25 | 32 | 153 | 20300 | 66 | 7120 | 409 | 4.0 | **1470** | <0.3 | 54 | 36 | 190 |
| | 5-10 cm | 17200 | <0.4 | 9.0 | 123 | 0.6 | 0.99 | 16800 | 26 | 46 | 212 | 22200 | 100 | 7400 | 453 | 4.1 | **1860** | <0.3 | 55 | 36 | 259 |
| | 10-20 cm | 19100 | <0.4 | **30.3** | 184 | 0.8 | 2.17 | 20900 | 38 | **129** | 745 | 46500 | **262** | 9270 | 680 | 5.4 | **9120** | 5.10 | 64 | 39 | 745 |
| 2292369 (Back yard) | 0-5 cm | 16200 | <0.4 | 18.2 | 162 | 0.7 | 1.43 | 21900 | 31 | **73** | **370** | 30300 | **213** | 7350 | 520 | 4.7 | **4310** | 1.70 | 70 | 33 | 405 |
| | 5-10 cm | 17200 | <0.4 | 24.0 | 163 | 0.7 | 1.47 | 22600 | 33 | **83** | **434** | 34000 | **205** | 7990 | 538 | 4.7 | **6430** | 1.80 | 69 | 33 | 414 |
| | 10-20 cm | 18500 | <0.4 | 23.8 | 177 | 0.8 | 1.46 | 26900 | 31 | **72** | **433** | 33900 | **206** | 8070 | 542 | 4.7 | **5100** | 1.80 | 78 | 35 | 420 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292370 (Front yard) | 0-5 cm | 17700 | <0.4 | 8.9 | 128 | 0.6 | 1.01 | 18700 | 27 | 42 | 176 | 24800 | 115 | 8290 | 505 | 4.4 | **1660** | <0.3 | 59 | 35 | 239 |
| | 5-10 cm | 17100 | <0.4 | 10.8 | 131 | 0.6 | 1.09 | 16000 | 31 | 50 | 204 | 26500 | 135 | 7600 | 550 | 4.5 | **2060** | <0.3 | 43 | 34 | 261 |
| | 10-20 cm | 22500 | <0.4 | 17.1 | 165 | 0.8 | 1.30 | 20100 | 39 | **66** | 276 | 36600 | 153 | 9070 | 644 | 4.7 | **3190** | 0.30 | 50 | 40 | 321 |
| 2292371 (Back yard) | 0-5 cm | 16300 | <0.4 | 16.1 | 198 | 0.9 | 1.51 | 18200 | 28 | **68** | **336** | 27600 | **206** | 5990 | 548 | 4.5 | **3030** | 1.20 | 69 | 32 | 413 |
| | 5-10 cm | 17100 | <0.4 | 20.5 | 233 | 0.8 | 1.56 | 19800 | 31 | **66** | **411** | 31900 | **224** | 6500 | 588 | 4.6 | **3750** | 0.30 | 74 | 34 | 461 |
| | 10-20 cm | 17400 | <0.4 | 20.5 | 231 | 0.8 | 1.50 | 20900 | 34 | **61** | **464** | 31900 | **236** | 6270 | 619 | 4.8 | **3600** | 0.30 | 82 | 33 | 465 |
| 2292372 (Front yard) | 0-5 cm | 21700 | <0.4 | 12.7 | 136 | 0.7 | 2.16 | 17700 | 35 | **61** | 214 | 27900 | 117 | 8140 | 444 | 4.8 | **2130** | <0.3 | 60 | 41 | 274 |
| | 0-5 cm | 20600 | <0.4 | 14.8 | 154 | 0.7 | 2.86 | 19200 | 33 | **56** | 231 | 27800 | 145 | 8810 | 463 | 4.8 | **2280** | 0.50 | 64 | 39 | 328 |
| | 0-5 cm | 20500 | <0.4 | 12.9 | 129 | 0.6 | 2.32 | 16000 | 31 | 49 | 207 | 28300 | 109 | 7340 | 411 | 4.5 | **2270** | <0.3 | 55 | 37 | 263 |
| | 5-10 cm | 25700 | <0.4 | 12.5 | 145 | 0.8 | 1.95 | 12500 | 35 | 50 | 202 | 30700 | 105 | 7140 | 451 | 4.4 | **2130** | <0.3 | 51 | 45 | 253 |
| | 5-10 cm | 22500 | <0.4 | 13.9 | 148 | 0.8 | 3.94 | 14600 | 36 | **61** | 230 | 30200 | 139 | 7900 | 480 | 4.3 | **2380** | <0.3 | 54 | 42 | 337 |
| | 5-10 cm | 23100 | <0.4 | 13.2 | 140 | 0.7 | 1.84 | 13000 | 33 | 47 | 201 | 29900 | 106 | 6370 | 440 | 4.2 | **2270** | <0.3 | 51 | 41 | 258 |
| | 10-20 cm | 23100 | <0.4 | 16.4 | 150 | 0.8 | 2.19 | 16600 | 36 | **62** | 284 | 32800 | 136 | 7460 | 501 | 4.6 | **3360** | <0.3 | 57 | 41 | 357 |
| | 10-20 cm | 21600 | <0.4 | 23.9 | 160 | 0.8 | 3.40 | 19600 | 38 | **90** | **423** | 41300 | 177 | 8880 | 567 | 5.3 | **5360** | 2.20 | 64 | 39 | 482 |
| | 10-20 cm | 21000 | <0.4 | 20.6 | 176 | 0.7 | 2.08 | 17900 | 43 | **73** | **339** | 36100 | 180 | 7010 | 485 | 4.9 | **4180** | 1.30 | 59 | 37 | 377 |
| 2292373 (Back yard) | 0-5 cm | 19200 | <0.4 | 10.7 | 149 | 0.7 | 1.30 | 13200 | 30 | 46 | 197 | 26900 | 188 | 5190 | 408 | 4.3 | **2060** | <0.3 | 48 | 38 | 287 |
| | 0-5 cm | 18200 | <0.4 | 9.1 | 154 | 0.8 | 1.17 | 17900 | 29 | 43 | 184 | 26100 | 162 | 6070 | 415 | 4.3 | **1890** | <0.3 | 53 | 37 | 301 |
| | 0-5 cm | 18300 | <0.4 | 10.2 | 155 | 0.9 | 1.25 | 14700 | 31 | 47 | 204 | 26600 | 183 | 5890 | 426 | 4.2 | **1960** | <0.3 | 53 | 38 | 345 |
| | 5-10 cm | 20300 | <0.4 | 11.7 | 174 | 1 | 1.27 | 11400 | 32 | 48 | 218 | 28400 | **207** | 5990 | 440 | 4.1 | **2200** | <0.3 | 53 | 40 | 390 |
| | 5-10 cm | 19200 | <0.4 | 10.2 | 152 | 0.8 | 1.07 | 11900 | 30 | 40 | 169 | 25300 | 158 | 5720 | 418 | 3.9 | **1660** | <0.3 | 46 | 39 | 289 |
| | 5-10 cm | 20100 | <0.4 | 11.5 | 171 | 0.9 | 1.23 | 10900 | 32 | 49 | 204 | 28300 | 188 | 5930 | 435 | 4.1 | **2170** | <0.3 | 51 | 40 | 355 |
| | 10-20 cm | 23500 | <0.4 | 18.8 | 311 | 1.2 | 1.67 | 19200 | 41 | **65** | **376** | 41300 | **438** | 7440 | 534 | 5.0 | **4260** | <0.3 | 78 | 43 | 559 |
| | 10-20 cm | 19300 | <0.4 | 13.8 | 203 | 1 | 1.28 | 26700 | 37 | 48 | 262 | 31300 | **236** | 7250 | 483 | 4.9 | **2780** | <0.3 | 75 | 39 | 385 |
| | 10-20 cm | 21900 | <0.4 | 23.5 | 301 | 1.2 | 1.89 | 21400 | 49 | **69** | **443** | 38400 | **463** | 7830 | 516 | 5.1 | **4470** | 0.90 | 86 | 44 | 615 |
| 2292374 (Front yard) | 0-5 cm | 18400 | <0.4 | 10.2 | 137 | 0.8 | 2.07 | 20700 | 31 | **56** | 206 | 30000 | 133 | 10300 | 485 | 4.6 | **2170** | <0.3 | 59 | 38 | 323 |
| | 5-10 cm | 20800 | <0.4 | 16.9 | 165 | 1 | 2.83 | 24000 | 37 | **73** | 300 | 40000 | 171 | 11700 | 679 | 5.0 | **3440** | 1.10 | 68 | 43 | 441 |
| | 10-20 cm | 21200 | <0.4 | 17.0 | 169 | 1.1 | 2.38 | 27400 | 36 | **56** | 276 | 40800 | 156 | 12600 | 623 | 5.0 | **3190** | <0.3 | 78 | 43 | 397 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292375 (Back yard) | 0-5 cm | 22700 | <0.4 | 6.7 | 157 | 0.9 | 1.64 | 12800 | 32 | 42 | 153 | 27000 | 138 | 7080 | 522 | 4.1 | **1380** | <0.3 | 48 | 44 | 278 |
| | 5-10 cm | 24400 | <0.4 | 7.1 | 161 | 1 | 1.69 | 10700 | 35 | 44 | 163 | 29600 | 130 | 6880 | 568 | 3.8 | **1440** | <0.3 | 44 | 47 | 276 |
| | 10-20 cm | 22800 | <0.4 | 4.7 | 145 | 0.9 | 1.36 | 9950 | 33 | 33 | 121 | 28800 | 97 | 6540 | 602 | 3.9 | **1100** | <0.3 | 38 | 45 | 225 |
| 2292376 (Front yard) | 0-5 cm | 20000 | <0.4 | 13.1 | 174 | 0.9 | 1.44 | 22000 | 36 | **68** | **319** | 32500 | **329** | 10100 | 470 | 4.7 | **3340** | 0.90 | 69 | 41 | 403 |
| | 5-10 cm | 25400 | <0.4 | 17.4 | 212 | 1.1 | 1.63 | 24200 | 42 | **73** | **375** | 40000 | 188 | 11000 | 537 | 4.9 | **4050** | 1.10 | 77 | 49 | 452 |
| | 10-20 cm | 30800 | 1.6 | 23.1 | 267 | **1.7** | 1.16 | 29300 | 40 | **62** | **303** | 42200 | 199 | 13000 | 533 | 1.2 | **2960** | 0.40 | 100 | 64 | 362 |
| 2292377 (Back yard) | 0-5 cm | 17200 | 1.5 | 14.6 | 190 | 1.1 | 1.56 | 45500 | 28 | **55** | 275 | 25900 | 174 | 23300 | 470 | 1.3 | **2300** | 1.00 | 111 | 40 | 380 |
| 2292378 (Back yard) | 0-5 cm | 16300 | 2.9 | 16.4 | 178 | 1 | 1.67 | 18200 | 26 | 50 | 252 | 22800 | **393** | 7550 | 343 | 0.7 | **2300** | 0.70 | 100 | 39 | 381 |
| | 5-10 cm | 15300 | 3.7 | 17.1 | 186 | 1 | 1.69 | 19300 | 26 | **52** | **328** | 23800 | **490** | 7700 | 363 | 0.7 | **2290** | 0.90 | 96 | 38 | 395 |
| | 10-20 cm | 17500 | 8.7 | **42.9** | 307 | 1.3 | 3.17 | 22000 | 40 | **117** | **694** | 43300 | **1140** | 8850 | 563 | 1.6 | **6670** | 3.80 | 130 | 48 | **938** |
| 2292379 (Front yard) | 0-5 cm | 11800 | 1.5 | 14.6 | 135 | 0.7 | 1.40 | 41400 | 33 | **130** | **640** | 22600 | **206** | 21400 | 514 | 1.3 | **3870** | 1.60 | 89 | 36 | 281 |
| | 5-10 cm | 14800 | 2.2 | **31.6** | 176 | 1 | 2.51 | 31200 | 38 | **220** | **1120** | 33400 | **331** | 16000 | 613 | 1.8 | **6320** | 4.30 | 82 | 47 | 501 |
| | 10-20 cm | 23400 | 1.5 | **28.4** | 226 | **1.4** | 2.30 | 31700 | 43 | **146** | **816** | 46600 | **246** | 14600 | 682 | 1.6 | **6060** | 1.00 | 93 | 54 | 470 |
| 2292380 (Back yard) | 0-5 cm | 29200 | 2 | 9.9 | 221 | **1.5** | 0.96 | 21300 | 42 | 41 | 163 | 35200 | **298** | 12900 | 605 | 1.0 | **1070** | <0.3 | 149 | 61 | 256 |
| | 5-10 cm | 30600 | 1.2 | 9.0 | 208 | **1.6** | 0.78 | 26100 | 46 | 36 | 132 | 34900 | 172 | 15100 | 612 | 1.1 | **869** | <0.3 | 147 | 63 | 225 |
| | 10-20 cm | 32800 | <0.4 | 9.3 | 206 | **1.6** | 0.69 | 24400 | 47 | 34 | 113 | 36200 | 131 | 13300 | 616 | 0.9 | **768** | <0.3 | 131 | 67 | 204 |
| 2292381 (Back yard) | 0-5 cm | 14900 | 2.8 | 10.9 | 297 | 0.8 | 2.84 | 54400 | 35 | 47 | 204 | 25500 | **594** | 23500 | 502 | 1.8 | **962** | 0.30 | 149 | 31 | 635 |
| 2292382 (Front yard) | 0-5 cm | 11900 | <0.4 | 9.1 | 115 | 0.8 | 0.81 | 26700 | 21 | 31 | 162 | 22800 | 103 | 10900 | 476 | 5.1 | **1060** | <0.3 | 79 | 25 | 179 |
| 2292382 (Back yard) | 0-5 cm | 21000 | 0.4 | 7.3 | 197 | **1.3** | 0.92 | 26300 | 32 | 28 | 113 | 30300 | 140 | 10400 | 594 | 4.6 | **666** | <0.3 | 99 | 37 | 208 |
| | 5-10 cm | 23800 | 0.5 | 5.7 | 219 | **1.5** | 0.89 | 26800 | 33 | 31 | 120 | 31900 | 160 | 10700 | 602 | 4.5 | **703** | <0.3 | 100 | 41 | 224 |
| | 10-20 cm | 24200 | 0.4 | 6.7 | 192 | **1.4** | 0.80 | 25600 | 34 | 28 | 108 | 30400 | 158 | 10200 | 541 | 4.7 | **620** | <0.3 | 108 | 43 | 200 |
| 2292384 (Front yard) | 0-5 cm | 11200 | <0.4 | 6.2 | 90 | 0.7 | 0.54 | 23000 | 18 | 15 | 73 | 16200 | 114 | 8530 | 322 | 4.1 | **563** | <0.3 | 73 | 23 | 136 |
| | 5-10 cm | 11100 | <0.4 | 8.4 | 96 | 0.7 | 0.57 | 24900 | 17 | 16 | 78 | 17300 | 105 | 8640 | 328 | 4.2 | **626** | <0.3 | 84 | 23 | 141 |
| | 10-20 cm | 10800 | <0.4 | 6.8 | 97 | 0.7 | 0.55 | 24700 | 17 | 17 | 74 | 16700 | 106 | 8120 | 314 | 4.1 | **702** | <0.3 | 92 | 23 | 132 |
| 2292385 (Back yard) | 0-5 cm | 18000 | <0.4 | 5.3 | 135 | 1 | 0.58 | 21800 | 25 | 20 | 69 | 22500 | 95 | 9030 | 448 | 4.0 | **502** | <0.3 | 90 | 34 | 151 |
| | 5-10 cm | 20800 | 0.4 | 5.9 | 144 | 1.1 | 0.57 | 23900 | 28 | 21 | 71 | 26400 | 103 | 9820 | 508 | 4.2 | **511** | <0.3 | 94 | 37 | 146 |
| | 10-20 cm | 21700 | 1.0 | 6.1 | 163 | 1.2 | 0.64 | 24000 | 31 | 23 | 84 | 27100 | 119 | 9830 | 477 | 4.4 | **576** | <0.3 | 110 | 40 | 170 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292386 (Front yard) | 0-5 cm | 11400 | <0.4 | 5.2 | 81 | 0.7 | 0.47 | 22800 | 17 | 13 | 52 | 15000 | 71 | 9150 | 275 | 3.9 | **400** | <0.3 | 81 | 23 | 114 |
| | 5-10 cm | 12000 | <0.4 | 5.5 | 86 | 0.7 | 0.48 | 24800 | 17 | 14 | 54 | 15700 | 76 | 9460 | 317 | 4.1 | **465** | <0.3 | 90 | 24 | 115 |
| | 10-20 cm | 9710 | <0.4 | 6.4 | 86 | 0.6 | 0.43 | 26200 | 15 | 13 | 48 | 16400 | 66 | 10300 | 371 | 4.0 | **435** | <0.3 | 102 | 21 | 100 |
| 2292387 (Back yard) | 0-5 cm | 13600 | <0.4 | 5.7 | 107 | 0.8 | 0.57 | 23100 | 21 | 17 | 64 | 19700 | 82 | 7780 | 378 | 4.1 | **489** | <0.3 | 97 | 26 | 140 |
| | 5-10 cm | 17700 | <0.4 | 7.1 | 135 | 1.1 | 0.56 | 25800 | 28 | 18 | 64 | 22500 | 89 | 8850 | 414 | 4.0 | **454** | <0.3 | 107 | 32 | 137 |
| | 10-20 cm | 14400 | <0.4 | 5.5 | 103 | 0.9 | 0.46 | 21500 | 20 | 15 | 50 | 19600 | 76 | 7360 | 349 | 3.7 | **418** | <0.3 | 91 | 29 | 112 |
| 2292388 (Front yard) | 0-5 cm | 12300 | <0.4 | 5.4 | 86 | 0.8 | 0.51 | 19900 | 18 | 14 | 53 | 16100 | 69 | 6930 | 331 | 3.8 | **478** | <0.3 | 76 | 24 | 127 |
| | 5-10 cm | 12300 | <0.4 | 5.9 | 88 | 0.8 | 0.55 | 21300 | 18 | 15 | 56 | 17200 | 70 | 7120 | 321 | 3.8 | **507** | <0.3 | 82 | 24 | 140 |
| | 10-20 cm | 13100 | <0.4 | 5.5 | 99 | 0.8 | 0.57 | 23800 | 19 | 15 | 66 | 17400 | 76 | 7030 | 338 | 3.9 | **523** | <0.3 | 99 | 25 | 139 |
| 2292389 (Back yard) | 0-5 cm | 9470 | <0.4 | 6.4 | 93 | 0.8 | 0.77 | 24500 | 15 | 18 | 79 | 18500 | 102 | 5300 | 442 | 3.8 | **861** | <0.3 | 76 | 18 | 203 |
| | 5-10 cm | 8940 | <0.4 | 7.8 | 91 | 0.8 | 0.75 | 25500 | 15 | 16 | 75 | 16900 | 104 | 5480 | 397 | 3.7 | **707** | <0.3 | 82 | 17 | 190 |
| | 10-20 cm | 10600 | <0.4 | 10.0 | 138 | **1.3** | 0.95 | 41700 | 17 | 22 | 110 | 20400 | 151 | 8030 | 487 | 4.4 | **1100** | <0.3 | 138 | 17 | 234 |
| 2292390 (Front yard) | 0-5 cm | 10200 | <0.4 | 5.0 | 79 | 0.6 | 0.46 | 22800 | 16 | 12 | 51 | 15300 | 49 | 6160 | 352 | 3.9 | **401** | <0.3 | 71 | 20 | 109 |
| | 5-10 cm | 11100 | <0.4 | 5.7 | 84 | 0.7 | 0.52 | 22300 | 18 | 15 | 58 | 17200 | 59 | 6860 | 365 | 3.7 | **527** | <0.3 | 73 | 23 | 130 |
| | 10-20 cm | 11400 | <0.4 | 6.7 | 87 | 0.8 | 0.53 | 24500 | 17 | 16 | 61 | 18300 | 66 | 7220 | 347 | 3.8 | **696** | <0.3 | 86 | 23 | 129 |
| 2292391 (Back yard) | 0-5 cm | 11000 | <0.4 | 7.8 | 121 | 1 | 1.02 | 28900 | 18 | 22 | 102 | 20600 | 174 | 6470 | 432 | 4.0 | **1030** | <0.3 | 96 | 20 | 256 |
| | 5-10 cm | 12100 | <0.4 | 9.2 | 132 | 1 | 1.02 | 32000 | 18 | 22 | 108 | 20300 | 171 | 7050 | 478 | 4.4 | **986** | <0.3 | 113 | 21 | 260 |
| | 10-20 cm | 10300 | <0.4 | 8.9 | 126 | 0.9 | 0.98 | 30000 | 18 | 26 | 112 | 21800 | **221** | 6600 | 470 | 4.5 | **1280** | <0.3 | 104 | 20 | 263 |
| 2292392 (Front yard) | 0-5 cm | 7180 | <0.4 | 14.6 | 155 | 0.7 | 1.85 | 43700 | 22 | 43 | 214 | 24200 | **278** | 20200 | 485 | 5.5 | **1910** | 1.30 | 149 | 17 | 442 |
| | 5-10 cm | 7450 | 0.4 | 19.8 | 161 | 0.7 | 2.56 | 47300 | 26 | **60** | 299 | 35700 | **282** | 19300 | 644 | 5.8 | **3010** | 1.70 | 149 | 18 | 488 |
| | 10-20 cm | 8780 | <0.4 | 17.6 | 201 | 0.8 | 1.70 | 32400 | 20 | 34 | 215 | 25700 | **304** | 7830 | 511 | 4.7 | **2190** | 0.60 | 132 | 16 | 422 |
| 2292393 (Back yard) | 0-5 cm | 10400 | <0.4 | 6.9 | 98 | 0.6 | 0.86 | 12900 | 18 | 26 | 111 | 22200 | 117 | 4550 | 491 | 3.8 | **1070** | <0.3 | 41 | 25 | 285 |
| | 5-10 cm | 8820 | 0.9 | 16.1 | 145 | 0.6 | 1.79 | 19700 | 24 | 48 | 242 | 32800 | **230** | 5480 | 596 | 4.4 | **2440** | 1.60 | 61 | 23 | 577 |
| | 10-20 cm | 7140 | 1.0 | 23.8 | 268 | 0.6 | 2.32 | 27800 | 24 | 42 | 293 | 33100 | **383** | 6240 | 574 | 4.7 | **2420** | 1.20 | 88 | 15 | 910 |
| 2292394 (Front yard) | 0-5 cm | 10300 | <0.4 | 14.2 | 120 | 0.7 | 1.51 | 18800 | 25 | 46 | 217 | 32700 | 196 | 7040 | 537 | 4.6 | **2420** | 1.20 | 63 | 24 | 370 |
| | 5-10 cm | 13100 | 0.4 | 19.2 | 152 | 0.9 | 2.02 | 20700 | 31 | **54** | 284 | 37000 | **253** | 7500 | 662 | 4.7 | **2890** | 1.90 | 67 | 26 | 467 |
| | 10-20 cm | 11500 | <0.4 | 17.2 | 148 | 0.8 | 1.64 | 23300 | 25 | 43 | 260 | 33200 | **229** | 6910 | 563 | 4.5 | **2820** | 0.70 | 64 | 25 | 442 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292395 (Back yard) | 0-5 cm | 13400 | <0.4 | 6.1 | 101 | 0.7 | 0.64 | 13900 | 18 | 18 | 70 | 18600 | 84 | 4830 | 491 | 3.8 | **589** | <0.3 | 46 | 27 | 169 |
| | 5-10 cm | 11300 | <0.4 | 13.3 | 136 | 0.7 | 1.17 | 19700 | 22 | 35 | 164 | 25500 | 166 | 5810 | 611 | 4.2 | **1400** | 0.40 | 62 | 27 | 329 |
| | 10-20 cm | 8770 | 0.7 | 19.2 | 188 | 0.7 | 1.62 | 27500 | 25 | 39 | 229 | 33700 | **253** | 6940 | 513 | 4.8 | **2120** | 0.70 | 75 | 22 | 491 |
| 2292396 (Front yard) | 0-5 cm | 18300 | 0.5 | 8.4 | 137 | 1 | 1.07 | 13500 | 28 | 32 | 141 | 28500 | **299** | 6470 | 493 | 4.1 | **1270** | <0.3 | 43 | 37 | 269 |
| | 0-5 cm | 18900 | 0.6 | 9.5 | 153 | 1 | 1.22 | 16600 | 29 | 36 | 162 | 29500 | **311** | 7390 | 514 | 4.4 | **1510** | <0.3 | 47 | 39 | 298 |
| | 0-5 cm | 19400 | 0.8 | 10.3 | 143 | 1 | 1.13 | 15400 | 30 | 36 | 164 | 32600 | **332** | 7010 | 551 | 4.3 | **1700** | <0.3 | 49 | 38 | 295 |
| | 5-10 cm | 22700 | 0.8 | 8.6 | 156 | 1.1 | 1.06 | 11900 | 32 | 34 | 145 | 31400 | **283** | 6890 | 529 | 3.9 | **1420** | <0.3 | 41 | 43 | 266 |
| | 5-10 cm | 26800 | 1.0 | 6.7 | 179 | 1.3 | 0.99 | 12200 | 35 | 30 | 127 | 32600 | **261** | 7580 | 591 | 4.0 | **1130** | <0.3 | 103 | 49 | 240 |
| | 5-10 cm | 21200 | 1.0 | 10.0 | 148 | 1 | 1.10 | 14600 | 31 | 37 | 178 | 33400 | **349** | 7220 | 581 | 4.3 | **1690** | <0.3 | 46 | 40 | 295 |
| | 10-20 cm | 15600 | 0.5 | 19.9 | 168 | 1 | 2.10 | 20800 | 36 | **65** | **312** | 47000 | **666** | 7570 | 657 | 5.0 | **3690** | 1.90 | 54 | 31 | 534 |
| | 10-20 cm | 15500 | 1.0 | 18.9 | 161 | 0.9 | 1.79 | 28100 | 32 | **56** | 290 | 43900 | **462** | 8560 | 726 | 5.1 | **3260** | 0.50 | 63 | 29 | 483 |
| | 10-20 cm | 19300 | 0.9 | 17.0 | 164 | 1 | 1.66 | 21800 | 35 | **52** | 270 | 42000 | **580** | 8060 | 663 | 4.8 | **2910** | <0.3 | 56 | 35 | 449 |
| 2292397 (Back yard) | 0-5 cm | 9060 | 1.7 | **27.1** | 236 | 0.6 | 2.37 | 22900 | 25 | 46 | 240 | 31500 | **448** | 5120 | 524 | 4.4 | **2630** | 1.30 | 94 | 22 | 726 |
| | 0-5 cm | 7640 | 0.8 | 25.0 | 183 | 0.6 | 2.56 | 24100 | 24 | 44 | 239 | 29200 | **393** | 5800 | 563 | 4.5 | **2260** | 1.90 | 93 | 20 | 556 |
| | 0-5 cm | 10000 | 1.8 | **30.1** | 235 | 0.7 | 2.48 | 24500 | 29 | 47 | 262 | 29500 | **510** | 5630 | 572 | 4.7 | **2380** | 3.00 | 107 | 23 | 683 |
| | 5-10 cm | 7060 | 1.5 | **37.2** | 238 | 0.6 | 2.48 | 31900 | 28 | 47 | 293 | 35400 | **464** | 6370 | 554 | 4.9 | **3010** | 1.10 | 116 | 17 | 752 |
| | 5-10 cm | 7490 | 1.6 | **41.9** | 284 | 0.7 | 2.95 | 36000 | 27 | 46 | **325** | 32400 | **549** | 6560 | 580 | 5.0 | **2940** | 3.20 | 141 | 15 | 719 |
| | 5-10 cm | 7320 | 2.9 | **38.9** | 248 | 0.7 | 2.61 | 31800 | 27 | 49 | **309** | 35800 | **583** | 6410 | 568 | 5.0 | **3230** | 2.40 | 119 | 17 | 685 |
| | 10-20 cm | 6240 | 1.2 | **29.4** | 217 | 0.6 | 2.02 | 37500 | 23 | 34 | 250 | 27800 | **408** | 6450 | 484 | 4.7 | **2220** | 0.80 | 146 | 14 | 570 |
| | 10-20 cm | 6070 | 1.2 | **27.3** | 225 | 0.5 | 2.05 | 35300 | 22 | 33 | 237 | 28200 | **406** | 6370 | 485 | 4.7 | **2140** | 1.90 | 131 | 14 | 589 |
| | 10-20 cm | 5930 | 1.5 | **29.3** | 244 | 0.6 | 2.01 | 35900 | 25 | 37 | 249 | 31600 | **454** | 6520 | 480 | 4.7 | **2560** | 1.80 | 136 | 14 | 709 |
| 2292398 (Front yard) | 0-5 cm* | 15550 | 0.4 | 9.2 | 126 | 0.8 | 0.96 | 15100 | 24 | 33 | 158 | 28600 | 197 | 6805 | 481 | 4.1 | **1575** | <0.3 | 54 | 33 | 260 |
| | 5-10 cm* | 16300 | 0.5 | 12.4 | 135 | 0.9 | 1.12 | 16350 | 26 | 37 | 186 | 32100 | **223** | 6735 | 497 | 4.2 | **1955** | 0.33 | 54 | 32 | 294 |
| | 10-20 cm* | 16850 | 0.3 | 14.0 | 149 | 0.9 | 1.19 | 24000 | 28 | 39 | 242 | 34350 | **246** | 8580 | 526 | 4.5 | **2165** | 0.38 | 69 | 33 | 385 |
| 2292399 (Back yard) | 0-5 cm* | 10045 | <0.4 | 13.5 | 92 | 0.5 | 1.00 | 13450 | 19 | 24 | 117 | 19550 | 137 | 3910 | 331 | 3.5 | **1130** | 0.28 | 55 | 23 | 235 |
| | 5-10 cm* | 10435 | <0.4 | 16.7 | 100 | 0.5 | 1.09 | 16300 | 20 | 24 | 124 | 20550 | 143 | 4330 | 343 | 3.6 | **1200** | <0.3 | 60 | 22 | 235 |
| | 10-20 cm* | 7935 | <0.4 | 24.1 | 148 | 0.5 | 1.44 | 25300 | 22 | 28 | 177 | 24250 | 199 | 5310 | 401 | 3.9 | **1660** | 0.66 | 99 | 17 | 311 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292400 (Front yard) | 0-5 cm | 17800 | 0.5 | 14.5 | 116 | 1 | 1.23 | 10100 | 27 | 36 | 177 | 28000 | 135 | 4170 | 581 | 3.7 | **1880** | 0.40 | 56 | 35 | 259 |
| | 5-10 cm | 19200 | 0.4 | 17.7 | 134 | 1 | 1.33 | 11400 | 29 | 38 | 193 | 31200 | 156 | 4430 | 626 | 4.0 | **2160** | 0.80 | 67 | 36 | 286 |
| | 10-20 cm | 14300 | 0.9 | 22.9 | 149 | 0.8 | 1.49 | 16800 | 27 | 45 | 246 | 35500 | **208** | 4420 | 528 | 4.2 | **3190** | 2.00 | 95 | 28 | 351 |
| 2292401 (Back yard) | 0-5 cm | 17400 | 1.0 | 10.3 | 131 | 0.9 | 1.05 | 13200 | 26 | 30 | 137 | 29900 | 182 | 4930 | 680 | 4.4 | **1380** | <0.3 | 59 | 35 | 299 |
| | 5-10 cm | 16700 | 1.0 | 10.1 | 127 | 0.9 | 1.03 | 12400 | 22 | 27 | 134 | 29800 | 190 | 5120 | 689 | 4.2 | **1360** | <0.3 | 54 | 27 | 283 |
| | 10-20 cm | 11700 | 0.6 | 11.5 | 165 | 0.8 | 1.09 | 21700 | 22 | 27 | 164 | 29600 | **230** | 5420 | 527 | 4.2 | **1650** | 0.40 | 93 | 27 | 362 |
| 2292402 (Front yard) | 0-5 cm | 20800 | 1.0 | 8.0 | 169 | 1 | 0.96 | 28300 | 31 | 24 | 99 | 29200 | **279** | 8640 | 536 | 4.7 | **818** | <0.3 | 85 | 39 | 253 |
| | 5-10 cm | 29000 | 0.8 | 4.9 | 198 | **1.3** | 0.79 | 27800 | 35 | 22 | 75 | 32300 | **215** | 9840 | 627 | 4.5 | **562** | <0.3 | 88 | 50 | 202 |
| | 10-20 cm | 29500 | <0.4 | 6.2 | 174 | **1.3** | 0.76 | 24800 | 35 | 27 | 92 | 34400 | 114 | 9260 | 660 | 4.4 | **742** | <0.3 | 79 | 51 | 166 |
| 2292403 (Back yard) | 0-5 cm | 18100 | 0.8 | 4.1 | 99 | 0.8 | 0.83 | 19200 | 22 | 14 | 57 | 19600 | 76 | 8870 | 587 | 4.2 | 191 | <0.3 | 83 | 34 | 171 |
| | 5-10 cm | 17500 | <0.4 | 3.0 | 92 | 0.8 | 0.71 | 21400 | 22 | 13 | 47 | 19100 | 59 | 8860 | 575 | 4.1 | 170 | <0.3 | 93 | 33 | 139 |
| | 10-20 cm | 17600 | 0.7 | 2.6 | 89 | 0.7 | 0.56 | 23700 | 21 | 12 | 44 | 18500 | 48 | 8560 | 539 | 4.2 | 137 | <0.3 | 114 | 33 | 118 |
| 2292404 (Front yard) | 0-5 cm | 23100 | <0.4 | 4.3 | 140 | 1.1 | 0.60 | 46500 | 28 | 21 | 64 | 24900 | 68 | 15300 | 544 | 4.9 | **295** | <0.3 | 109 | 40 | 148 |
| | 5-10 cm | 23700 | <0.4 | 6.1 | 145 | 1.2 | 0.78 | 47800 | 29 | 28 | 87 | 27600 | 98 | 15900 | 571 | 4.7 | **509** | <0.3 | 119 | 42 | 182 |
| | 10-20 cm | 14300 | <0.4 | 10.6 | 109 | 0.8 | 1.10 | 28900 | 24 | 36 | 136 | 23800 | 148 | 9250 | 497 | 4.4 | **962** | <0.3 | 90 | 30 | 260 |
| 2292405 (Back yard) | 0-5 cm | 16800 | 0.5 | 3.3 | 97 | 0.7 | 0.50 | 12000 | 20 | 11 | 41 | 19500 | 65 | 5700 | 387 | 3.5 | 170 | <0.3 | 51 | 32 | 114 |
| | 5-10 cm | 16300 | 0.4 | 6.5 | 126 | 0.7 | 0.75 | 19400 | 21 | 16 | 60 | 22300 | 121 | 7000 | 433 | 3.8 | **432** | <0.3 | 65 | 31 | 195 |
| | 10-20 cm | 6830 | 1.9 | 19.6 | 264 | 0.5 | 2.15 | 28800 | 23 | 32 | 219 | 31900 | **417** | 6190 | 550 | 4.3 | **1660** | 1.10 | 95 | 16 | 635 |
| 2292406 (Front yard) | 0-5 cm | 18300 | 0.5 | 3.1 | 93 | 0.8 | 0.52 | 12400 | 21 | 14 | 55 | 18200 | 53 | 5590 | 366 | 3.5 | **313** | <0.3 | 69 | 35 | 102 |
| | 5-10 cm | 22500 | <0.4 | 5.9 | 132 | 1 | 0.69 | 21200 | 26 | 21 | 108 | 21400 | 80 | 7820 | 403 | 3.9 | **639** | <0.3 | 106 | 42 | 140 |
| | 10-20 cm | 24600 | 0.7 | 7.6 | 155 | 1.2 | 0.98 | 30200 | 30 | 23 | 122 | 25100 | 111 | 10000 | 446 | 4.5 | **721** | <0.3 | 162 | 44 | 201 |
| 2292407 (Back yard) | 0-5 cm | 16300 | <0.4 | 13.9 | 233 | 1.1 | 1.64 | 21000 | 30 | 32 | 187 | 29400 | **258** | 6520 | 536 | 4.2 | **1400** | <0.3 | 115 | 33 | 465 |
| | 5-10 cm | 16100 | 2.1 | 22.2 | 373 | **1.3** | 2.41 | 27800 | 40 | 48 | **325** | 43200 | **394** | 7130 | 740 | 5.2 | **2680** | 1.00 | 163 | 32 | 743 |
| | 10-20 cm | 16400 | 3.1 | **37.9** | 451 | **1.4** | 3.25 | 32900 | 59 | 52 | **392** | 49200 | **617** | 6960 | 852 | 5.8 | **3070** | 1.80 | 215 | 30 | **1000** |
| 2292408 (Front yard) | 0-5 cm | 23200 | <0.4 | 5.9 | 124 | 1.1 | 0.84 | 15900 | 34 | 25 | 95 | 29000 | 99 | 8800 | 534 | 4.2 | **769** | <0.3 | 57 | 45 | 176 |
| | 5-10 cm | 26400 | <0.4 | 5.8 | 136 | **1.3** | 0.81 | 16900 | 37 | 25 | 94 | 30000 | 96 | 9470 | 552 | 4.1 | **710** | <0.3 | 58 | 49 | 169 |
| | 10-20 cm | 29200 | <0.4 | 4.7 | 144 | **1.3** | 0.61 | 19800 | 37 | 20 | 63 | 30400 | 68 | 11000 | 561 | 4.2 | **461** | <0.3 | 55 | 52 | 131 |

### Table 6-3: Results of Chemical Analysis (μg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292409 (Back yard) | 0-5 cm | 19900 | <0.4 | 12.2 | 173 | 1 | 1.62 | 15400 | 32 | 31 | 203 | 30300 | **286** | 6780 | 514 | 4.4 | **1250** | <0.3 | 94 | 40 | 383 |
| | 5-10 cm | 23600 | 0.4 | 15.6 | 210 | 1.2 | 1.76 | 15200 | 37 | 34 | 190 | 36300 | **259** | 6410 | 526 | 4.6 | **1630** | <0.3 | 117 | 43 | 402 |
| | 10-20 cm | 17000 | 1.3 | **29.7** | 699 | 1.1 | 2.82 | 23900 | 43 | 49 | **1620** | 47300 | **534** | 5480 | 628 | 5.5 | **2800** | 2.20 | 209 | 30 | 923 |
| 2292410 (Front yard) | 0-5 cm | 17800 | <0.4 | 5.5 | 119 | 0.9 | 0.81 | 26100 | 26 | 19 | 95 | 22200 | 119 | 11300 | 497 | 4.1 | **600** | <0.3 | 83 | 35 | 181 |
| | 5-10 cm* | 18400 | 0.4 | 7.8 | 132 | 0.9 | 0.97 | 26900 | 30 | 18 | 86 | 24350 | 125 | 11000 | 578 | 3.1 | **593** | 0.51 | 86 | 37 | 207 |
| | 10-20 cm* | 22850 | 0.5 | 11.9 | 190 | 1.2 | 0.93 | 25350 | 34 | 25 | 133 | 30375 | **201** | 10600 | 605 | 3.1 | **1218** | 0.55 | 136 | 45 | 246 |
| 2292411 (Back yard) | 0-5 cm* | 13650 | 1.8 | 8.6 | 99 | 0.5 | 1.07 | 26300 | 27 | 14 | 72 | 18825 | 91 | 10000 | 500 | 2.9 | **361** | 0.38 | 80 | 29 | 189 |
| | 5-10 cm* | 12950 | 2 | 7 | 101 | 1 | 1.40 | 37950 | 30 | 13 | 83 | 20450 | 124 | 13775 | 562 | 3 | **469** | 0 | 83 | 28 | 242 |
| | 10-20 cm* | 12975 | 2.3 | 7.5 | 130 | 0.6 | 1.69 | 47175 | 33 | 16 | 116 | 22325 | **276** | 17275 | 571 | 3.9 | **618** | 0.40 | 132 | 28 | 302 |
| 2292412 (Back yard) | 0-5 cm | 16700 | <0.4 | 7.5 | 229 | 1 | 1.95 | 27800 | 30 | 45 | 226 | 23500 | **307** | 12000 | 420 | 4.4 | **1640** | <0.3 | 87 | 46 | 493 |
| | 5-10 cm | 17100 | <0.4 | 8 | 223 | 1 | 2.07 | 29800 | 28 | 46 | 241 | 24700 | **341** | 12700 | 436 | 4 | **1530** | <0.3 | 89 | 63 | 489 |
| | 10-20 cm* | 15600 | 2.5 | 13.0 | 318 | 1 | 2.38 | 37300 | 31 | 50 | 326 | 25275 | **446** | 14775 | 463 | 3.7 | **2318** | 1.25 | 111 | 54 | 637 |
| 2292413 (Back yard) | 0-5 cm | 21600 | <0.4 | 11.0 | 194 | 1 | 1.07 | 24200 | 35 | 49 | 210 | 24100 | 173 | 10200 | 463 | 4.6 | **1290** | <0.3 | 63 | 41 | 354 |
| | 5-10 cm | 25000 | <0.4 | 11 | 223 | 1 | 1.18 | 18700 | 36 | 43 | 208 | 26900 | 190 | 8080 | 485 | 4 | **1510** | <0.3 | 62 | 47 | 386 |
| | 10-20 cm* | 23525 | 1.9 | 15.7 | 202 | 1 | 1.11 | 18025 | 35 | 43 | 217 | 27550 | 174 | 7343 | 540 | 3.0 | **1863** | 1.10 | 58 | 43 | 388 |
| 2292414 (Back yard) | 0-5 cm | 20300 | 1.0 | 21.8 | 285 | 1.2 | 2.00 | 21200 | 35 | **83** | **427** | 31100 | **254** | 8500 | 468 | 4.2 | **3640** | 1.40 | 92 | 42 | 636 |
| | 5-10 cm | 20700 | 0.8 | 20.3 | 282 | 1.1 | 1.92 | 17900 | 34 | **82** | **426** | 29900 | **257** | 7170 | 469 | 4.2 | **3280** | 1.40 | 77 | 42 | 638 |
| | 10-20 cm | 20150 | 2.5 | 22.3 | 288 | 1 | 1.78 | 16400 | 36 | **95** | **438** | 31750 | **280** | 6850 | 525 | 3.1 | **3893** | 2.03 | 70 | 43 | **813** |
| 2292415 (Front yard) | 0-5 cm* | 8523 | 1.2 | 3.9 | 82 | 0.4 | 0.26 | 42950 | 12 | 7 | 34 | 14125 | 14 | 6463 | 595 | 2.3 | 48 | 0.23 | 81 | 20 | 66 |
| | 5-10 cm* | 11975 | 1.3 | 4.3 | 90 | 0.5 | 0.43 | 32325 | 18 | 16 | 57 | 16625 | 31 | 6193 | 562 | 2.2 | 272 | 0.38 | 69 | 26 | 97 |
| | 10-20 cm | 20900 | <0.4 | 5.3 | 134 | 1 | 0.93 | 21300 | 30 | 42 | 143 | 22800 | 89 | 6650 | 492 | 3.9 | **1000** | <0.3 | 64 | 42 | 161 |
| 2292416 (Back yard) | 0-5 cm | 30300 | <0.4 | 10.6 | 205 | **1.5** | 1.28 | 12900 | 42 | **69** | 265 | 29500 | 182 | 6520 | 441 | 3.9 | **2210** | 0.70 | 71 | 56 | 274 |
| | 5-10 cm | 32500 | <0.4 | 11.1 | 224 | **1.7** | 1.03 | 13700 | 40 | **58** | 251 | 33100 | 183 | 7740 | 464 | 3.7 | **2430** | <0.3 | 68 | 59 | 259 |
| | 10-20 cm | 29200 | <0.4 | 19.9 | 255 | **1.6** | 1.35 | 18100 | 41 | **61** | **346** | 37600 | **260** | 7660 | 471 | 4.1 | **3930** | 0.80 | 87 | 54 | 404 |
| 2292417 (Front yard) | 0-5 cm | 19800 | <0.4 | 7.6 | 133 | 1 | 0.85 | 25600 | 29 | **67** | 246 | 23500 | 169 | 14600 | 471 | 4.2 | **2120** | <0.3 | 143 | 41 | 246 |
| 2292418 (Back yard) | 0-5 cm | 19400 | 1.3 | 17.5 | 254 | **1.3** | 1.96 | 24000 | 40 | **93** | **396** | 32100 | **308** | 9760 | 504 | 4.7 | **4030** | 2.20 | 95 | 42 | 699 |
| | 5-10 cm | 22400 | 1.7 | 18.7 | 330 | **1.6** | 1.77 | 30800 | 49 | **67** | **328** | 32600 | **334** | 12300 | 492 | 5.5 | **3470** | 1.20 | 140 | 49 | 825 |
| | 10-20 cm | 28200 | <0.4 | 13.0 | 232 | **1.5** | 1.12 | 24600 | 41 | **54** | 254 | 33800 | **204** | 14100 | 496 | 4.5 | **2510** | <0.3 | 90 | 53 | 341 |

### Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292419 (Front yard) | 0-5 cm | 15200 | <0.4 | 12.0 | 167 | 0.8 | 1.64 | 15400 | 32 | **134** | **388** | 23500 | **324** | 6920 | 492 | 3.7 | **3750** | 2.80 | 47 | 37 | 400 |
| | 5-10 cm | 16600 | 0.5 | 15.6 | 145 | 0.9 | 1.80 | 13000 | 31 | **122** | **421** | 25800 | **256** | 5940 | 469 | 3.7 | **4320** | 4.40 | 43 | 38 | 360 |
| | 10-20 cm | 19500 | <0.4 | 15.0 | 135 | 1 | 1.17 | 11700 | 30 | **74** | **329** | 30200 | 129 | 6050 | 588 | 3.7 | **4190** | 1.60 | 40 | 40 | 266 |
| 2292420 (Back yard) | 0-5 cm | 15000 | 0.5 | 12.5 | 148 | 0.8 | 2.17 | 16100 | 30 | **103** | **364** | 24400 | 176 | 6950 | 480 | 3.7 | **2990** | 2.70 | 102 | 32 | 289 |
| | 5-10 cm | 15500 | <0.4 | 14.6 | 132 | 0.9 | 2.25 | 14200 | 29 | **93** | **367** | 25300 | 144 | 6750 | 531 | 3.6 | **3210** | 2.20 | 84 | 32 | 269 |
| | 10-20 cm | 16400 | <0.4 | 15.0 | 157 | 0.9 | 1.11 | 19500 | 26 | **141** | **459** | 27100 | 151 | 7750 | 472 | 3.8 | **3660** | 1.40 | 131 | 32 | 240 |
| 2292421 (Front yard) | 0-5 cm | 22500 | 1.1 | 15.0 | 178 | 1.2 | 1.73 | 11900 | 42 | **151** | **514** | 32000 | **292** | 7090 | 738 | 4.1 | **5080** | 2.90 | 44 | 46 | 573 |
| | 5-10 cm | 26100 | <0.4 | 10.4 | 161 | **1.4** | 1.27 | 10800 | 35 | **79** | 288 | 30300 | 153 | 7960 | 838 | 3.7 | **2860** | 0.70 | 37 | 47 | 407 |
| | 10-20 cm | 26600 | 0.7 | 15.2 | 172 | **1.4** | 1.17 | 15100 | 38 | **71** | **337** | 33700 | 176 | 9650 | 680 | 4.4 | **4210** | 2.10 | 42 | 46 | 370 |
| 2292422 (Back yard) | 0-5 cm | 16700 | <0.4 | 5.0 | 103 | 0.8 | 0.79 | 15800 | 22 | 29 | 105 | 18400 | 101 | 7680 | 344 | 3.4 | **963** | <0.3 | 45 | 33 | 150 |
| | 5-10 cm | 17900 | <0.4 | 5.9 | 111 | 0.9 | 0.85 | 17500 | 23 | 31 | 115 | 20300 | 111 | 8440 | 378 | 3.4 | **1070** | <0.3 | 47 | 34 | 157 |
| | 10-20 cm | 15700 | <0.4 | 7.8 | 99 | 0.8 | 0.79 | 22900 | 21 | 29 | 120 | 20100 | 127 | 9230 | 389 | 3.7 | **1360** | <0.3 | 59 | 31 | 162 |
| 2292423 (Front yard) | 0-5 cm | 19800 | 3.0 | 15.1 | 180 | **1.3** | 1.74 | 19300 | 36 | 90 | **394** | 32300 | **201** | 7010 | 492 | 4.4 | **4400** | 1.90 | 76 | 40 | 374 |
| | 5-10 cm | 22100 | 2.1 | 13.0 | 178 | **1.4** | 1.25 | 17800 | 30 | **53** | 268 | 29700 | 160 | 6470 | 422 | 3.6 | **2740** | 0.90 | 76 | 40 | 277 |
| | 10-20 cm | 25100 | 5.8 | 23.3 | 276 | **1.8** | 1.55 | 23700 | 40 | **63** | **354** | 39900 | **324** | 7200 | 465 | 4.5 | **4780** | <0.3 | 125 | 42 | 408 |
| 2292424 (Front yard) | 0-5 cm | 16200 | 0.6 | 12.1 | 169 | 1.1 | 1.28 | 24200 | 31 | **68** | **301** | 26300 | **205** | 9480 | 476 | 4.2 | **3140** | 0.70 | 83 | 36 | 377 |
| | 5-10 cm | 18500 | 1.3 | 18.2 | 207 | **1.5** | 1.47 | 24100 | 34 | **77** | **400** | 29300 | **246** | 9260 | 474 | 4.2 | **4060** | 1.30 | 124 | 38 | 514 |
| | 10-20 cm | 18600 | 1.6 | **26.7** | 201 | **1.3** | 1.63 | 25600 | 34 | **82** | **454** | 33700 | **223** | 9650 | 428 | 4.4 | **5580** | 2.20 | 117 | 38 | 453 |
| 2292425 (Back yard) | 0-5 cm | 19800 | <0.4 | 6.0 | 161 | 1.1 | 1.45 | 20800 | 28 | 44 | 149 | 23500 | 155 | 8750 | 482 | 3.6 | **1200** | <0.3 | 71 | 37 | 257 |
| | 5-10 cm | 25000 | <0.4 | 5.3 | 184 | **1.3** | 0.99 | 22400 | 31 | 38 | 125 | 27600 | 130 | 10300 | 519 | 3.6 | **967** | <0.3 | 74 | 43 | 221 |
| | 10-20 cm | 20900 | <0.4 | 7.7 | 141 | 1.1 | 0.88 | 24000 | 26 | 40 | 163 | 26800 | 93 | 10300 | 477 | 3.7 | **1550** | <0.3 | 61 | 37 | 185 |
| 2292426 (Front yard) | 0-5 cm | 20000 | <0.4 | 4.3 | 123 | 1 | 0.70 | 20700 | 27 | 32 | 106 | 22000 | 99 | 12700 | 456 | 3.9 | **799** | <0.3 | 73 | 41 | 168 |
| | 5-10 cm | 20200 | <0.4 | 4.5 | 119 | 1.1 | 0.62 | 22500 | 27 | 30 | 94 | 22000 | 89 | 13300 | 478 | 3.9 | **687** | <0.3 | 66 | 41 | 152 |
| | 10-20 cm | 19800 | <0.4 | 4.3 | 121 | 1 | 0.86 | 23200 | 27 | 27 | 103 | 23300 | 131 | 13900 | 554 | 4.1 | **894** | <0.3 | 57 | 39 | 173 |
| 2292427 (Front yard) | 0-5 cm | 19700 | <0.4 | 5.0 | 119 | 1 | 0.80 | 13900 | 26 | 34 | 143 | 21300 | 96 | 6960 | 357 | 3.7 | **1120** | <0.3 | 55 | 40 | 196 |
| | 5-10 cm | 24500 | <0.4 | 6.4 | 143 | 1.2 | 0.86 | 11900 | 32 | 40 | 163 | 24700 | 110 | 6820 | 438 | 3.6 | **1320** | <0.3 | 53 | 46 | 226 |
| | 10-20 cm | 24500 | <0.4 | 6.5 | 152 | 1.2 | 0.82 | 11900 | 31 | 42 | 185 | 25400 | 160 | 6890 | 422 | 3.7 | **1680** | <0.3 | 50 | 44 | 219 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292428 (Back yard) | 0-5 cm | 22100 | <0.4 | 7.9 | 201 | 1.2 | 2.65 | 14400 | 32 | 39 | 206 | 25400 | 154 | 6480 | 364 | 4.0 | **1690** | <0.3 | 83 | 43 | 312 |
| | 5-10 cm | 29100 | <0.4 | 9.6 | 266 | **1.6** | 1.60 | 15800 | 41 | 49 | 256 | 30100 | **206** | 7360 | 431 | 4.1 | **2000** | <0.3 | 101 | 51 | 400 |
| | 10-20 cm | 29500 | <0.4 | 14.1 | 330 | **1.7** | 1.85 | 13600 | 41 | **56** | 276 | 33000 | 189 | 7180 | 460 | 4.2 | **2830** | <0.3 | 123 | 52 | 401 |
| 2292429 (Front yard) | 0-5 cm | 10300 | <0.4 | 5.3 | 68 | 0.6 | 0.49 | 11800 | 17 | 30 | 124 | 16300 | 95 | 5630 | 402 | 3.4 | **1080** | <0.3 | 34 | 29 | 143 |
| | 5-10 cm | 10600 | <0.4 | 3.4 | 61 | 0.6 | 0.44 | 9450 | 16 | 23 | 93 | 14800 | 73 | 4620 | 391 | 3.1 | **719** | <0.3 | 30 | 28 | 105 |
| | 10-20 cm | 11300 | <0.4 | 8.6 | 102 | 0.7 | 0.77 | 13900 | 19 | 48 | 217 | 19700 | 134 | 6250 | 443 | 3.5 | **2010** | 0.50 | 39 | 30 | 225 |
| 2292430 (Back yard) | 0-5 cm | 16300 | 0.6 | 17.1 | 242 | 1.2 | 2.09 | 19300 | 34 | **82** | **366** | 30000 | **623** | 7230 | 500 | 4.5 | **3360** | 2.80 | 87 | 37 | 625 |
| | 5-10 cm | 20600 | 1.5 | **26.9** | 352 | **1.4** | 2.56 | 21000 | 39 | **91** | **516** | 36700 | **797** | 7470 | 555 | 4.7 | **5070** | 2.80 | 103 | 43 | 742 |
| | 10-20 cm | 23700 | 5.7 | **28.6** | 565 | **1.8** | 2.27 | 28900 | 49 | **74** | **522** | 37500 | **1460** | 8130 | 576 | 4.7 | **4960** | 1.40 | 209 | 47 | **916** |
| 2292431 (Front yard) | 0-5 cm | 16400 | <0.4 | 16.0 | 182 | 1 | 1.36 | 20300 | 31 | **79** | **414** | 30100 | **401** | 7940 | 492 | 4.1 | **3400** | 1.60 | 70 | 41 | 639 |
| | 5-10 cm | 16200 | <0.4 | 19.7 | 155 | 1 | 1.38 | 19600 | 29 | **84** | **442** | 31600 | **328** | 8180 | 507 | 4.3 | **4120** | 2.50 | 65 | 41 | 533 |
| | 10-20 cm | 15600 | <0.4 | 21.2 | 168 | 1 | 1.21 | 19200 | 26 | **62** | **419** | 31100 | **250** | 6540 | 496 | 3.9 | **3380** | 2.00 | 76 | 39 | 403 |
| 2292432 (Back yard) | 0-5 cm | 19800 | <0.4 | 17.3 | 244 | 1.2 | 1.91 | 16500 | 37 | **74** | **408** | 31200 | **386** | 6450 | 548 | 4.4 | **3920** | 1.20 | 78 | 42 | 592 |
| | 5-10 cm | 22100 | 1.4 | 20.0 | 274 | **1.4** | 2.16 | 15000 | 39 | **84** | **465** | 34400 | **531** | 6190 | 635 | 4.3 | **4730** | 1.90 | 82 | 45 | 632 |
| | 10-20 cm | 21900 | 1.1 | 24.7 | 292 | **1.4** | 1.90 | 16100 | 36 | **75** | **468** | 34700 | **485** | 6060 | 618 | 4.1 | **4890** | 2.20 | 91 | 44 | 571 |
| 2292433 (Front yard) | 0-5 cm | 19400 | 1.9 | 10.6 | 168 | 1.2 | 1.54 | 28400 | 33 | **60** | 299 | 23800 | **274** | 12300 | 439 | 4.6 | **2290** | 0.80 | 114 | 34 | 494 |
| | 0-5 cm | 21700 | 1.7 | 8.8 | 174 | **1.3** | 1.52 | 23900 | 38 | **60** | 278 | 24000 | **287** | 9710 | 449 | 4.3 | **2240** | <0.3 | 95 | 37 | 505 |
| | 0-5 cm | 23200 | 3.2 | 8.9 | 196 | **1.3** | 1.69 | 24300 | 39 | **62** | 288 | 24100 | **313** | 10300 | 466 | 4.4 | **2180** | 0.30 | 97 | 41 | 605 |
| | 5-10 cm | 22400 | 2.1 | 12.5 | 198 | **1.4** | 1.70 | 28600 | 41 | **78** | **382** | 26900 | **348** | 12600 | 483 | 4.7 | **2930** | 1.30 | 118 | 38 | 598 |
| | 5-10 cm | 23200 | 2.4 | 11.8 | 203 | **1.4** | 1.74 | 24400 | 39 | **81** | **360** | 27800 | **347** | 10800 | 482 | 4.5 | **3010** | <0.3 | 97 | 41 | 629 |
| | 5-10 cm | 26200 | 4.6 | 15.0 | 215 | **1.5** | 2.14 | 27300 | 50 | **120** | **489** | 29800 | **518** | 12800 | 564 | 4.7 | **3640** | 1.40 | 104 | 49 | **930** |
| | 10-20 cm | 29700 | 3.0 | 16.1 | 248 | **1.8** | 1.85 | 27900 | 44 | **89** | **493** | 35300 | **368** | 12200 | 519 | 4.6 | **4900** | 1.00 | 161 | 45 | 705 |
| | 10-20 cm | 25400 | 2.9 | 22.4 | 231 | **1.6** | 2.27 | 27000 | 43 | **132** | **597** | 40500 | **383** | 11900 | 587 | 4.9 | **6310** | 2.00 | 110 | 43 | **801** |
| | 10-20 cm | 28900 | 4.6 | 19.6 | 285 | **1.8** | 2.20 | 25400 | 47 | **122** | **564** | 38100 | **459** | 11600 | 555 | 4.8 | **5430** | 1.30 | 116 | 49 | **839** |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292434 (Back yard) | 0-5 cm | 21900 | 0.8 | 11.0 | 164 | **1.3** | 1.05 | 10300 | 29 | **65** | 278 | 29400 | **209** | 4030 | 482 | 3.8 | **2870** | 1.00 | 61 | 38 | 358 |
| | 0-5 cm | 21300 | 0.7 | 10.4 | 169 | 1.2 | 1.06 | 10300 | 27 | **63** | 261 | 28500 | 194 | 3910 | 458 | 3.7 | **2700** | 0.70 | 62 | 37 | 363 |
| | 0-5 cm | 23300 | 0.5 | 10.9 | 178 | **1.3** | 1.12 | 10400 | 30 | **70** | 283 | 30300 | **209** | 4370 | 486 | 3.8 | **3080** | 0.70 | 62 | 43 | 365 |
| | 5-10 cm | 23700 | 1.4 | 12.7 | 192 | **1.6** | 1.09 | 11100 | 32 | **66** | **326** | 34700 | **219** | 4160 | 547 | 3.9 | **3630** | 1.10 | 68 | 39 | 380 |
| | 5-10 cm | 23300 | 0.9 | 12.6 | 192 | **1.4** | 1.19 | 11300 | 30 | **72** | **312** | 34800 | **253** | 4270 | 577 | 3.7 | **3480** | 0.60 | 69 | 38 | 461 |
| | 5-10 cm | 26300 | 0.7 | 15.8 | 200 | **1.5** | 1.28 | 11700 | 33 | **71** | **329** | 34300 | **226** | 4680 | 542 | 3.9 | **3510** | 0.80 | 70 | 44 | 391 |
| | 10-20 cm | 27800 | 0.6 | 11.1 | 258 | **1.6** | 0.97 | 15100 | 35 | 46 | 270 | 33600 | **251** | 5040 | 521 | 4.0 | **2660** | <0.3 | 89 | 43 | 355 |
| | 10-20 cm | 26900 | 0.4 | 8.8 | 194 | **1.4** | 0.83 | 10300 | 32 | 44 | 200 | 32200 | 172 | 4760 | 520 | 3.8 | **2180** | <0.3 | 68 | 43 | 301 |
| | 10-20 cm | 30600 | 0.6 | 15.6 | 321 | **1.8** | 1.26 | 13900 | 39 | **59** | 325 | 38900 | **320** | 5560 | 505 | 4.1 | **3910** | 0.30 | 106 | 50 | 434 |
| 2292435 (Back yard) | 0-5 cm | 25900 | 5.1 | 17.8 | 258 | **1.4** | 2.32 | 17300 | 38 | **84** | **471** | 33400 | **316** | 6870 | 549 | 4.2 | **3690** | 1.70 | 90 | 48 | 516 |
| | 5-10 cm | 29500 | 1.2 | 22.5 | 238 | **1.6** | 1.65 | 17000 | 41 | **98** | **671** | 38900 | **473** | 7190 | 666 | 4.4 | **4880** | 1.20 | 93 | 52 | 459 |
| | 10-20 cm | 31700 | 0.8 | 23.2 | 297 | **1.8** | 1.73 | 25000 | 58 | **149** | **1230** | 41400 | **261** | 7720 | 540 | 4.3 | **6390** | 1.60 | 149 | 48 | 503 |
| 2292436 (Back yard) | 0-5 cm | 13400 | <0.4 | 7.1 | 125 | 0.7 | 1.50 | 16000 | 22 | 29 | 103 | 20200 | **228** | 7270 | 543 | 3.4 | **809** | <0.3 | 62 | 27 | 213 |
| 2292437 (Front yard) | 0-5 cm* | 14100 | 1.6 | 7.1 | 87 | 0.7 | 0.77 | 15750 | 23 | 30 | 134 | 20800 | 84 | 7185 | 556 | 2.3 | **984** | 0.60 | 42 | 34 | 140 |
| | 5-10 cm* | 14700 | 1.6 | 8.9 | 91 | 0.7 | 0.82 | 15300 | 24 | 33 | 147 | 21925 | 93 | 7015 | 621 | 2.2 | **1086** | 0.58 | 42 | 34 | 144 |
| | 10-20 cm* | 14125 | 1.5 | 6.8 | 79 | 0.7 | 0.63 | 16250 | 21 | 21 | 96 | 21350 | 57 | 6175 | 625 | 2.1 | **690** | 0.48 | 42 | 32 | 102 |
| 2292438 (Back yard) | 0-5 cm* | 14775 | 1.5 | 8.8 | 90 | 0.8 | 0.82 | 19150 | 22 | 28 | 124 | 19450 | 123 | 6338 | 512 | 2.3 | **1230** | 0.73 | 52 | 31 | 204 |
| | 5-10 cm* | 14900 | 1.9 | 10.9 | 121 | 0.8 | 0.83 | 18750 | 23 | 29 | 130 | 20500 | 127 | 6560 | 519 | 2.3 | **1313** | 0.73 | 52 | 33 | 214 |
| | 10-20 cm* | 15425 | 1.9 | 12.2 | 135 | 0.9 | 0.76 | 20925 | 23 | 30 | 148 | 21950 | 142 | 7028 | 509 | 2.9 | **1566** | 0.68 | 61 | 34 | 219 |
| 2292439 (Front yard) | 0-5 cm | 21200 | <0.4 | 10 | 135 | 1 | 0.97 | 13400 | 29 | **56** | 216 | 25400 | 106 | 8380 | 471 | 5 | **2190** | 2 | 42 | 44 | 216 |
| | 5-10 cm | 24300 | <0.4 | 10.0 | 150 | **1.4** | 0.89 | 15900 | 31 | 48 | 187 | 27700 | 95 | 9830 | 531 | 5.1 | **1900** | <0.3 | 42 | 47 | 192 |
| | 10-20 cm* | 25900 | 0.4 | 10.4 | 171 | **1.3** | 0.76 | 28350 | 34 | 39 | 184 | 29825 | 79 | 11800 | 601 | 2.8 | **1683** | 0.73 | 65 | 48 | 206 |
| 2292440 (Back yard) | 0-5 cm | 16300 | <0.4 | 17.1 | 185 | 1.2 | 1.41 | 15600 | 25 | 40 | 202 | 20900 | **202** | 6300 | 401 | 5.0 | **1930** | 0.90 | 75 | 35 | 322 |
| | 5-10 cm* | 15650 | 0.5 | 18.8 | 191 | 1 | 1.26 | 18075 | 25 | 40 | 219 | 20200 | **223** | 6223 | 403 | 2.5 | **2098** | 1.04 | 82 | 34 | 338 |
| | 10-20 cm* | 18700 | 0.7 | **27.6** | 261 | **1.3** | 1.53 | 19625 | 30 | 48 | 233 | 23775 | **272** | 6490 | 459 | 2.6 | **2863** | 1.75 | 118 | 39 | 408 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292441 (Front yard) | 0-5 cm | 21900 | <0.4 | 15.2 | 171 | **1.4** | 1.54 | 23600 | 33 | **71** | **322** | 23900 | 144 | 10300 | 452 | 5.8 | **3050** | 1.10 | 70 | 48 | 282 |
| | 0-5 cm | 21200 | <0.4 | 16.5 | 174 | **1.4** | 1.65 | 24400 | 35 | **74** | **343** | 24200 | 151 | 10600 | 430 | 5.7 | **3240** | 2.20 | 73 | 47 | 286 |
| | 0-5 cm | 22100 | <0.4 | 19.2 | 186 | **1.4** | 1.65 | 24000 | 33 | **80** | **385** | 24800 | 151 | 10200 | 424 | 5.6 | **3950** | 0.90 | 71 | 47 | 304 |
| | 5-10 cm | 22800 | <0.4 | 20 | 182 | 1 | 1.73 | 23400 | 33 | **84** | **426** | 27200 | 157 | 10300 | 467 | 6 | **4480** | 3 | 74 | 49 | 329 |
| | 5-10 cm | 22300 | <0.4 | 21.0 | 180 | **1.4** | 1.77 | 23800 | 34 | **87** | **427** | 28000 | **201** | 10100 | 485 | 5.6 | **4680** | 2.90 | 70 | 48 | 318 |
| | 5-10 cm | 21100 | <0.4 | 24 | 172 | 1 | 2.11 | 24300 | 35 | **110** | **507** | 29600 | 187 | 10800 | 472 | 6 | **6330** | 4 | 69 | 46 | 356 |
| | 10-20 cm | 22700 | 1 | 24 | 182 | 1 | 0.92 | 26200 | 33 | **78** | **466** | 28400 | 146 | 9867 | 472 | 2 | **5077** | 3 | 77 | 47 | 314 |
| | 10-20 cm* | 19733 | 0.6 | 24.4 | 179 | 1.1 | 1.05 | 25433 | 30 | **82** | **462** | 27567 | 170 | 9583 | 453 | 2.5 | **5440** | 3.00 | 71 | 43 | 346 |
| | 10-20 cm* | 21925 | 0.5 | 22.8 | 176 | 1.2 | 1.06 | 24025 | 32 | **82** | **460** | 28650 | 148 | 9103 | 441 | 2.8 | **5328** | 1.70 | 72 | 45 | 302 |
| 2292442 (Back yard) | 0-5 cm* | 14900 | 0.5 | 13.6 | 122 | 0.9 | 1.14 | 14933 | 23 | 36 | 192 | 17500 | 118 | 6197 | 289 | 2.2 | **1813** | 1.77 | 61 | 33 | 264 |
| | 0-5 cm | 13700 | <0.4 | 13.0 | 107 | 0.9 | 1.12 | 13900 | 20 | 36 | 177 | 16400 | 100 | 5790 | 273 | 4.7 | **1680** | 1.10 | 52 | 31 | 230 |
| | 0-5 cm | 14700 | <0.4 | 12.2 | 122 | 1 | 1.21 | 14800 | 22 | 36 | 171 | 17900 | 102 | 6150 | 282 | 4.8 | **1670** | 0.90 | 59 | 34 | 231 |
| | 5-10 cm* | 16200 | 0.5 | 16.0 | 134 | 1 | 1.14 | 15933 | 24 | 38 | 214 | 18333 | 136 | 6500 | 294 | 2.1 | **2017** | 1.63 | 68 | 35 | 271 |
| | 5-10 cm* | 13775 | 1 | 15 | 118 | 1 | 0.98 | 16150 | 21 | 38 | 207 | 16825 | 117 | 6308 | 271 | 2 | **2046** | 1 | 58 | 31 | 263 |
| | 5-10 cm | 15200 | <0.4 | 14 | 127 | 1 | 1.32 | 14700 | 23 | 45 | 223 | 18800 | 114 | 6450 | 301 | 5 | **2300** | 2 | 61 | 35 | 245 |
| | 10-20 cm* | 13400 | 1 | 17 | 143 | 1 | 1.11 | 20567 | 22 | 32 | 205 | 17633 | 124 | 7067 | 281 | 2 | **1990** | 1 | 88 | 29 | 291 |
| | 10-20 cm* | 10400 | 0.4 | 16.4 | 102 | 0.7 | 0.84 | 18700 | 18 | 36 | 237 | 15625 | 91 | 6108 | 238 | 2.3 | **2146** | 1.14 | 65 | 25 | 258 |
| | 10-20 cm* | 13800 | 0.5 | 21.6 | 157 | 0.9 | 1.34 | 19950 | 23 | 37 | 233 | 18075 | 125 | 7093 | 278 | 2.6 | **2198** | 1.19 | 71 | 29 | 312 |
| 2292443 (Front yard) | 0-5 cm | 21800 | <0.4 | 16.0 | 153 | **1.3** | 1.68 | 13700 | 34 | **83** | **356** | 27200 | 170 | 8090 | 593 | 5.6 | **3670** | 1.10 | 42 | 49 | 522 |
| | 5-10 cm | 20300 | <0.4 | **29.7** | 159 | **1.3** | 2.71 | 15300 | 38 | **164** | **709** | 37700 | **218** | 8930 | 712 | 5.9 | **8900** | 5.20 | 40 | 49 | 789 |
| | 10-20 cm* | 19000 | 1 | 21 | 145 | 1 | 0.97 | 18600 | 29 | **72** | **493** | 27367 | 158 | 8257 | 551 | 2 | **5387** | 2 | 43 | 42 | 414 |
| 2292444 (Back yard) | 0-5 cm | 19700 | <0.4 | 9.2 | 135 | 1.2 | 0.95 | 13500 | 29 | 32 | 148 | 22300 | 98 | 7970 | 483 | 4.9 | **1240** | 1.50 | 49 | 43 | 255 |
| | 5-10 cm | 19800 | <0.4 | 12.1 | 142 | i.2 | 1.00 | 16300 | 29 | 35 | 162 | 23100 | 97 | 9250 | 490 | 5.1 | **1400** | <0.3 | 51 | 42 | 255 |
| | 10-20 cm* | 14033 | 0.7 | 17.6 | 159 | 0.9 | 0.78 | 20133 | 26 | 39 | 240 | 21933 | **240** | 7203 | 341 | 2.6 | **2287** | 0.95 | 76 | 36 | 329 |
| 2292445 (Front yard) | 0-5 cm | 26000 | 1.2 | 16.0 | 245 | **1.7** | 1.84 | 19700 | 154 | **56** | **314** | 27000 | 179 | 9040 | 447 | 5.5 | **2910** | 1.30 | 93 | 54 | 626 |
| | 5-10 cm | 28600 | 1.7 | 18.6 | 270 | **1.8** | 2.09 | 19900 | 245 | **63** | **359** | 28300 | 187 | 9410 | 449 | 5.5 | **3390** | 0.90 | 90 | 55 | **827** |
| | 10-20 cm* | 26475 | 1.1 | 19.1 | 242 | **1.6** | 1.42 | 20525 | 183 | **52** | **323** | 27100 | 167 | 8980 | 440 | 2.8 | **3170** | 1.59 | 89 | 50 | 673 |
| 2292446 (Back yard) | 0-5 cm* | 15250 | 0.4 | 8.2 | 136 | 1.2 | 0.88 | 17975 | 29 | 24 | 134 | 19875 | 120 | 8393 | 526 | 2.8 | **1086** | 0.63 | 121 | 34 | 339 |
| | 5-10 cm* | 15300 | 0.4 | 7.8 | 127 | **1.3** | 0.87 | 19650 | 28 | 24 | 120 | 19925 | 110 | 8833 | 529 | 2.7 | **1038** | 0.58 | 135 | 34 | 319 |
| | 10-20 cm* | 19800 | 1 | 16 | 243 | **3** | 1.14 | 20900 | 35 | 31 | 195 | 22067 | **224** | 8070 | 462 | 4 | **1527** | 1 | 273 | 45 | 451 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292447 (Front yard) | 0-5 cm | 20400 | 9.4 | 7.6 | 216 | 1.1 | 1.20 | 20000 | 32 | 43 | 179 | 25200 | **524** | 9330 | 539 | 4.5 | **1620** | <0.3 | 63 | 41 | 311 |
| | 5-10 cm | 21200 | 8.8 | 7.5 | 176 | 1.1 | 1.05 | 18300 | 31 | 40 | 157 | 25800 | **360** | 8730 | 460 | 4.2 | **1430** | <0.3 | 56 | 41 | 246 |
| | 10-20 cm | 17800 | 8.0 | 7.9 | 153 | 1 | 1.44 | 28000 | 27 | 35 | 153 | 26200 | **278** | 11100 | 479 | 4.4 | **1670** | <0.3 | 65 | 35 | 222 |
| 2292448 (Back yard) | 0-5 cm | 26200 | **23.6** | 9.7 | 409 | **1.4** | 1.60 | 27600 | 40 | 43 | 225 | 32700 | **1340** | 9600 | 505 | 4.5 | **2190** | <0.3 | 102 | 48 | 583 |
| | 5-10 cm | 26300 | **19.1** | 8.5 | 329 | **1.4** | 1.45 | 23100 | 38 | 42 | 210 | 31900 | **1010** | 8650 | 463 | 4.5 | **2000** | <0.3 | 96 | 48 | 490 |
| | 10-20 cm | 25500 | **18.7** | 12.0 | 366 | **1.4** | 1.83 | 25600 | 41 | 49 | **312** | 35600 | **1130** | 9520 | 512 | 4.6 | **2660** | <0.3 | 101 | 47 | 645 |
| 2292449 (Front yard) | 0-5 cm* | 16175 | 2.6 | 15.0 | 147 | 0.9 | 1.38 | 25775 | 30 | 43 | 224 | 30500 | 177 | 11000 | 532 | 3.5 | **1975** | 1.39 | 86 | 36 | 335 |
| | 5-10 cm* | 19075 | 2.7 | 14.6 | 154 | 1 | 1.30 | 28500 | 31 | 38 | 188 | 32025 | 155 | 11900 | 550 | 3.4 | **1790** | 0.90 | 77 | 40 | 297 |
| | 10-20 cm* | 19075 | 2.6 | 13.4 | 139 | 1 | 1.04 | 24850 | 29 | 32 | 159 | 31375 | 126 | 10250 | 524 | 3.4 | **1610** | 0.83 | 64 | 39 | 260 |
| 2292450 (Back yard) | 0-5 cm* | 9820 | 2.2 | 15.6 | 160 | 0.6 | 1.39 | 22350 | 23 | 28 | 175 | 23625 | **227** | 6805 | 417 | 2.6 | **1470** | 1.23 | 115 | 28 | 353 |
| | 5-10 cm | 9610 | 6.9 | 16.0 | 138 | 0.7 | 1.35 | 21500 | 24 | 28 | 151 | 24100 | **207** | 6600 | 442 | 5.0 | **1310** | 0.55 | 105 | 29 | 316 |
| | 10-20 cm* | 9593 | 2.4 | 17.8 | 149 | 0.6 | 1.26 | 23275 | 21 | 28 | 180 | 24400 | **206** | 6700 | 413 | 2.6 | **1648** | 0.87 | 120 | 26 | 319 |
| 2292451 (Front yard) | 0-5 cm* | 13750 | 1.7 | 7.1 | 87 | 0.7 | 1.00 | 14400 | 22 | 21 | 106 | 20150 | 95 | 5813 | 360 | 2.4 | **909** | 0.60 | 58 | 30 | 172 |
| | 5-10 cm* | 13725 | 1.7 | 7.6 | 84 | 0.7 | 0.98 | 14525 | 22 | 22 | 112 | 20125 | 105 | 5760 | 351 | 2.3 | **896** | 0.60 | 58 | 30 | 166 |
| | 10-20 cm* | 12375 | 1.9 | 13.3 | 104 | 0.6 | 1.43 | 14450 | 23 | 38 | 211 | 27350 | 162 | 4838 | 430 | 2.8 | **1933** | 1.13 | 64 | 27 | 295 |
| 2292452 (Front yard) | 0-5 cm | 19900 | 5.6 | 7.8 | 168 | 1 | 0.98 | 17400 | 32 | 23 | 100 | 22300 | 167 | 9180 | 428 | 5.0 | **667** | <0.3 | 70 | 42 | 255 |
| | 5-10 cm* | 19975 | 1.7 | 7.9 | 152 | 0.9 | 1.00 | 11750 | 28 | 21 | 93 | 22950 | 158 | 6735 | 427 | 2.4 | **686** | 0.58 | 58 | 41 | 235 |
| | 10-20 cm* | 20000 | 1.8 | 6.9 | 152 | 0.9 | 0.96 | 10148 | 28 | 20 | 88 | 23725 | 162 | 6135 | 409 | 2.2 | **607** | 0.50 | 47 | 40 | 229 |
| 2292453 (Back yard) | 0-5 cm* | 12900 | 2.0 | 10.8 | 186 | 0.6 | 1.19 | 10875 | 23 | 18 | 130 | 18450 | **309** | 3833 | 445 | 2.6 | **606** | 0.58 | 76 | 34 | 343 |
| | 5-10 cm* | 12775 | 1.4 | 9.1 | 182 | 0.6 | 1.10 | 10528 | 21 | 18 | 115 | 18850 | **266** | 3640 | 482 | 2.1 | **601** | 0.63 | 74 | 33 | 302 |
| | 10-20 cm* | 12400 | 1.6 | 9.6 | 168 | 0.6 | 0.93 | 10650 | 20 | 18 | 160 | 18600 | **242** | 3463 | 433 | 2.6 | **660** | 0.55 | 72 | 32 | 287 |
| 2292454 (Front yard) | 0-5 cm* | 12725 | 1.4 | 10.8 | 111 | 0.6 | 1.01 | 16825 | 21 | 28 | 136 | 19575 | 166 | 7175 | 402 | 2.7 | **1078** | 0.73 | 66 | 29 | 249 |
| | 5-10 cm* | 13750 | 1.3 | 9.0 | 90 | 0.5 | 0.86 | 11975 | 19 | 27 | 118 | 18875 | 129 | 5863 | 361 | 2.5 | **982** | 0.68 | 47 | 29 | 200 |
| | 10-20 cm* | 14200 | 2.0 | 18.0 | 152 | 0.8 | 1.21 | 23225 | 25 | 45 | 227 | 30425 | 199 | 10825 | 571 | 3.6 | **2360** | 1.89 | 88 | 30 | 324 |
| 2292455 (Back yard) | 0-5 cm* | 12225 | 1.0 | 5.8 | 75 | 0.4 | 0.72 | 6853 | 18 | 17 | 73 | 14625 | **208** | 2713 | 236 | 2.3 | **438** | 0.60 | 41 | 26 | 237 |
| | 5-10 cm | 13600 | 3.0 | 3.4 | 64 | 0.5 | 0.64 | 5040 | 17 | 16 | 57 | 16300 | 103 | 2480 | 239 | 2.9 | **380** | <0.3 | 33 | 29 | 158 |
| | 10-20 cm | 14200 | 2.9 | 4.9 | 77 | 0.6 | 0.66 | 5660 | 18 | 17 | 83 | 16700 | 106 | 2610 | 221 | 2.9 | **568** | <0.3 | 45 | 27 | 148 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292456 (Front yard) | 0-5 cm | 11200 | 4.9 | 19.1 | 215 | 0.9 | 1.96 | 32700 | 33 | 49 | 293 | 26500 | **462** | 13100 | 513 | 5.1 | **2280** | 2.53 | 143 | 30 | 520 |
| | 5-10 cm | 11700 | 5.0 | **25.4** | 291 | 1.1 | 2.27 | 32600 | 37 | **66** | **371** | 37200 | **676** | 10500 | 595 | 5.3 | **3260** | 2.91 | 183 | 31 | 629 |
| | 10-20 cm | 12400 | 6.6 | **31.7** | 311 | 1.2 | 2.53 | 30000 | 40 | **68** | **435** | 48100 | **662** | 9930 | 672 | 5.4 | **4830** | 4.37 | 195 | 32 | 692 |
| 2292457 (Back yard) | 0-5 cm | 13100 | 3.1 | 5.0 | 68 | 0.5 | 0.81 | 8580 | 18 | 17 | 70 | 16300 | 104 | 3740 | 285 | 3.3 | **487** | <0.3 | 46 | 29 | 176 |
| | 5-10 cm | 13000 | 2.6 | 4.0 | 56 | 0.5 | 0.64 | 7130 | 17 | 15 | 59 | 15700 | 84 | 3540 | 255 | 3.2 | **425** | <0.3 | 35 | 28 | 146 |
| | 10-20 cm | 12300 | 3.1 | 5.7 | 78 | 0.6 | 0.75 | 8450 | 19 | 17 | 87 | 17600 | 175 | 3520 | 259 | 3.3 | **666** | <0.3 | 48 | 26 | 182 |
| 2292458 (Front yard) | 0-5 cm | 22600 | <0.4 | 5.5 | 134 | 1.1 | 0.94 | 11500 | 33 | 30 | 120 | 19900 | 93 | 7030 | 448 | 4.0 | **709** | <0.3 | 48 | 49 | 161 |
| | 5-10 cm | 22300 | <0.4 | 4.6 | 127 | 1.1 | 0.80 | 11200 | 30 | 26 | 101 | 19400 | 76 | 6970 | 400 | 3.6 | **601** | <0.3 | 46 | 47 | 138 |
| | 10-20 cm | 22400 | <0.4 | 5.7 | 124 | 1.1 | 0.74 | 12200 | 30 | 26 | 102 | 21500 | 71 | 7520 | 466 | 4.0 | **696** | <0.3 | 49 | 46 | 142 |
| 2292459 (Back yard) | 0-5 cm | 15000 | <0.4 | 6.2 | 90 | 0.7 | 0.98 | 6050 | 21 | 26 | 118 | 17900 | 101 | 3150 | 289 | 3.2 | **864** | <0.3 | 27 | 33 | 212 |
| | 5-10 cm | 14400 | <0.4 | 4.2 | 71 | 0.7 | 0.67 | 4580 | 18 | 17 | 67 | 14500 | 61 | 2650 | 229 | 2.6 | **442** | <0.3 | 22 | 30 | 132 |
| | 10-20 cm | 17100 | <0.4 | 12.7 | 137 | 1 | 1.57 | 11600 | 27 | 35 | 160 | 24200 | 149 | 4960 | 383 | 3.8 | **1670** | <0.3 | 48 | 35 | 319 |
| 2292460 (Front yard) | 0-5 cm | 16100 | <0.4 | 4.9 | 89 | 0.9 | 0.57 | 9700 | 23 | 18 | 91 | 21100 | 61 | 5600 | 520 | 3.5 | **579** | <0.3 | 35 | 34 | 123 |
| | 5-10 cm | 16500 | <0.4 | 6.2 | 92 | 0.9 | 0.59 | 10200 | 24 | 20 | 98 | 22400 | 71 | 5790 | 546 | 3.6 | **666** | <0.3 | 38 | 34 | 129 |
| | 10-20 cm | 19000 | <0.4 | 9.0 | 111 | 1.1 | 0.89 | 14000 | 30 | 31 | 178 | 27200 | 113 | 7260 | 511 | 4.0 | **1310** | <0.3 | 52 | 39 | 192 |
| 2292461 (Back yard) | 0-5 cm | 17000 | <0.4 | 8.5 | 105 | 1 | 0.91 | 13600 | 26 | 26 | 114 | 20700 | 74 | 6240 | 393 | 3.9 | **1070** | <0.3 | 71 | 37 | 164 |
| | 5-10 cm | 18200 | <0.4 | 8.6 | 110 | 1.1 | 0.91 | 13200 | 26 | 26 | 113 | 21400 | 72 | 6130 | 377 | 3.7 | **1020** | <0.3 | 75 | 38 | 160 |
| | 10-20 cm | 21700 | <0.4 | 8.0 | 122 | 1.2 | 0.91 | 11400 | 29 | 25 | 110 | 23800 | 76 | 6040 | 425 | 3.8 | **1100** | <0.3 | 72 | 41 | 165 |
| 2292462 (Front yard) | 0-5 cm | 15700 | <0.4 | 7.6 | 97 | 0.9 | 0.78 | 12100 | 25 | 22 | 95 | 21100 | 91 | 6740 | 435 | 4.2 | **749** | <0.3 | 39 | 35 | 187 |
| | 5-10 cm | 17300 | <0.4 | 8.0 | 101 | 0.9 | 0.74 | 12500 | 25 | 23 | 102 | 22700 | 87 | 7590 | 459 | 3.9 | **780** | <0.3 | 42 | 38 | 177 |
| | 10-20 cm | 18500 | <0.4 | 10.8 | 117 | 1 | 0.99 | 15400 | 28 | 30 | 144 | 26800 | 119 | 9160 | 469 | 4.2 | **1250** | <0.3 | 53 | 39 | 234 |
| 2292463 (Back yard) | 0-5 cm | 14400 | <0.4 | 9.0 | 92 | 0.8 | 1.01 | 12500 | 21 | 22 | 109 | 17900 | 77 | 4500 | 407 | 3.7 | **903** | <0.3 | 59 | 33 | 174 |
| | 5-10 cm | 13900 | <0.4 | 9.5 | 91 | 0.8 | 0.93 | 11000 | 21 | 23 | 109 | 18000 | 71 | 4610 | 374 | 3.4 | **987** | <0.3 | 57 | 33 | 161 |
| | 10-20 cm | 15200 | <0.4 | 8.1 | 91 | 0.8 | 0.78 | 9810 | 21 | 19 | 91 | 17900 | 53 | 4480 | 361 | 3.3 | **790** | <0.3 | 54 | 33 | 143 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292464 (Front yard) | 0-5 cm | 19600 | <0.4 | 8.3 | 125 | 1.1 | 0.99 | 15300 | 30 | 27 | 111 | 24200 | 91 | 8710 | 436 | 4.3 | **884** | <0.3 | 69 | 42 | 216 |
| | 0-5 cm | 24800 | <0.4 | 8.5 | 141 | 1.3 | 1.01 | 12500 | 36 | 28 | 113 | 26900 | 89 | 7350 | 468 | 4.4 | **937** | <0.3 | 60 | 53 | 212 |
| | 0-5 cm | 24400 | <0.4 | 8.9 | 144 | 1.3 | 1.05 | 12800 | 37 | 29 | 116 | 26100 | 104 | 7660 | 426 | 4.2 | **966** | <0.3 | 61 | 53 | 254 |
| | 5-10 cm | 22300 | <0.4 | 8.6 | 133 | 1.2 | 0.99 | 13700 | 32 | 28 | 116 | 27100 | 88 | 8180 | 453 | 4.3 | **972** | <0.3 | 65 | 45 | 210 |
| | 5-10 cm | 28400 | <0.4 | 7.7 | 154 | **1.4** | 0.97 | 11100 | 38 | 29 | 112 | 29900 | 86 | 7540 | 487 | 4.1 | **934** | <0.3 | 61 | 58 | 204 |
| | 5-10 cm | 27800 | <0.4 | 7.1 | 152 | **1.3** | 0.97 | 10900 | 37 | 27 | 103 | 28500 | 86 | 7440 | 486 | 4.0 | **812** | <0.3 | 61 | 56 | 219 |
| | 10-20 cm | 21700 | <0.4 | 11.0 | 138 | 1.2 | 1.01 | 13400 | 32 | 31 | 136 | 28500 | 96 | 7520 | 443 | 4.0 | **1240** | <0.3 | 60 | 44 | 226 |
| | 10-20 cm | 27900 | <0.4 | 8.9 | 154 | **1.4** | 1.01 | 12000 | 38 | 30 | 121 | 30300 | 88 | 7780 | 468 | 4.2 | **1070** | <0.3 | 60 | 57 | 207 |
| | 10-20 cm | 26900 | <0.4 | 10.3 | 155 | **1.4** | 1.03 | 11300 | 37 | 30 | 124 | 30000 | 97 | 7350 | 451 | 4.0 | **1150** | <0.3 | 62 | 55 | 226 |
| 2292465 (Back yard) | 0-5 cm | 20100 | <0.4 | 7.1 | 121 | 1.1 | 1.00 | 12800 | 29 | 21 | 93 | 20200 | 80 | 6060 | 356 | 3.9 | **618** | <0.3 | 74 | 44 | 214 |
| | 0-5 cm | 18900 | <0.4 | 7.6 | 116 | 1 | 0.95 | 13200 | 28 | 20 | 86 | 19000 | 71 | 6200 | 327 | 3.8 | **677** | <0.3 | 72 | 42 | 191 |
| | 0-5 cm | 19700 | <0.4 | 6.8 | 119 | 1 | 0.93 | 12800 | 29 | 21 | 88 | 19400 | 94 | 6090 | 338 | 3.8 | **604** | <0.3 | 77 | 43 | 193 |
| | 5-10 cm | 19400 | <0.4 | 6.6 | 114 | 1 | 0.93 | 13400 | 27 | 21 | 90 | 19200 | 74 | 6140 | 360 | 3.8 | **638** | 0.30 | 71 | 42 | 180 |
| | 5-10 cm | 20600 | <0.4 | 7.3 | 125 | 1.1 | 0.96 | 14500 | 30 | 22 | 93 | 20600 | 76 | 6660 | 359 | 3.8 | **636** | <0.3 | 81 | 45 | 201 |
| | 5-10 cm | 20400 | <0.4 | 7.3 | 123 | 1.1 | 0.98 | 13400 | 29 | 22 | 92 | 19800 | 76 | 6340 | 349 | 3.9 | **689** | <0.3 | 84 | 45 | 190 |
| | 10-20 cm | 19600 | <0.4 | 7.8 | 115 | 1 | 0.91 | 14500 | 28 | 20 | 84 | 19800 | 68 | 6190 | 344 | 3.8 | **622** | <0.3 | 79 | 43 | 174 |
| | 10-20 cm | 20100 | <0.4 | 8.1 | 125 | 1.1 | 0.94 | 15300 | 28 | 21 | 93 | 19600 | 73 | 6600 | 339 | 3.9 | **694** | <0.3 | 85 | 42 | 193 |
| | 10-20 cm | 21100 | <0.4 | 8.2 | 125 | 1.1 | 0.96 | 14100 | 29 | 21 | 91 | 20500 | 74 | 6240 | 347 | 3.8 | **700** | <0.3 | 90 | 44 | 189 |
| 2292466 (Front yard) | 0-5 cm | 16100 | <0.4 | 5.4 | 88 | 0.8 | 0.60 | 12900 | 23 | 20 | 71 | 21600 | 64 | 6350 | 447 | 3.8 | **646** | <0.3 | 38 | 37 | 140 |
| | 5-10 cm | 17900 | <0.4 | 5.7 | 97 | 0.9 | 0.64 | 9910 | 25 | 22 | 75 | 22800 | 65 | 5810 | 490 | 3.8 | **562** | <0.3 | 30 | 41 | 138 |
| | 10-20 cm | 18900 | <0.4 | 5.0 | 95 | 0.9 | 0.55 | 7900 | 25 | 19 | 59 | 22600 | 52 | 5550 | 490 | 3.6 | **444** | <0.3 | 25 | 40 | 116 |
| 2292467 (Back yard) | 0-5 cm | 22700 | <0.4 | 4.7 | 155 | 1.2 | 0.52 | 21100 | 32 | 18 | 55 | 26200 | 161 | 9330 | 590 | 4.4 | **274** | <0.3 | 77 | 48 | 158 |
| | 5-10 cm | 24100 | <0.4 | 6.0 | 174 | 1.3 | 0.59 | 23900 | 34 | 22 | 67 | 28600 | 143 | 10300 | 597 | 4.5 | **413** | <0.3 | 91 | 50 | 188 |
| | 10-20 cm | 18600 | <0.4 | 8.3 | 172 | 1.1 | 0.83 | 20900 | 30 | 26 | 108 | 26700 | 197 | 9080 | 524 | 4.7 | **804** | <0.3 | 93 | 41 | 250 |
| 2292468 (Front yard) | 0-5 cm | 16500 | <0.4 | 9.4 | 118 | 1 | 0.91 | 17000 | 25 | 29 | 147 | 24800 | 119 | 7170 | 597 | 4.4 | **1160** | <0.3 | 52 | 38 | 218 |
| | 5-10 cm | 17400 | <0.4 | 10.5 | 130 | 1.1 | 1.15 | 17400 | 28 | 33 | 168 | 26200 | 133 | 7410 | 646 | 4.6 | **1250** | <0.3 | 57 | 41 | 246 |
| | 10-20 cm | 14200 | <0.4 | 7.3 | 85 | 0.8 | 0.79 | 10900 | 22 | 27 | 120 | 24900 | 90 | 5190 | 601 | 3.9 | **1030** | <0.3 | 36 | 33 | 181 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292469 (Back yard) | 0-5 cm | 14100 | <0.4 | 14.6 | 175 | 0.8 | 1.40 | 24100 | 31 | 24 | 158 | 21000 | **271** | 6940 | 487 | 4.7 | **974** | <0.3 | 97 | 32 | 332 |
| | 5-10 cm | 15200 | <0.4 | 18.0 | 220 | 1.1 | 1.71 | 24400 | 32 | 30 | 217 | 26100 | **389** | 6930 | 567 | 4.4 | **1360** | <0.3 | 108 | 35 | 396 |
| | 10-20 cm | 14600 | <0.4 | 14.0 | 167 | 0.9 | 1.13 | 14800 | 26 | 24 | 125 | 24500 | **296** | 5390 | 583 | 4.1 | **979** | <0.3 | 73 | 32 | 270 |
| 2292470 (Front yard) | 0-5 cm | 13100 | <0.4 | 7.7 | 133 | 0.8 | 1.19 | 24700 | 24 | 27 | 148 | 17700 | **234** | 9220 | 395 | 4.3 | **775** | <0.3 | 77 | 32 | 243 |
| | 0-5 cm | 11100 | <0.4 | 6.4 | 118 | 0.7 | 0.89 | 20500 | 21 | 23 | 122 | 15600 | 192 | 7870 | 333 | 4.1 | **720** | <0.3 | 62 | 30 | 203 |
| | 0-5 cm | 12300 | <0.4 | 7.9 | 121 | 0.8 | 1.27 | 23400 | 24 | 27 | 147 | 18600 | **203** | 9730 | 394 | 4.4 | **840** | <0.3 | 74 | 32 | 235 |
| | 5-10 cm | 13700 | <0.4 | 7.6 | 134 | 0.8 | 1.04 | 22500 | 25 | 28 | 156 | 18000 | **232** | 7850 | 385 | 4.2 | **806** | <0.3 | 69 | 34 | 236 |
| | 5-10 cm | 14900 | <0.4 | 8.8 | 150 | 0.9 | 1.28 | 23600 | 27 | 32 | 177 | 20000 | **271** | 8250 | 425 | 4.3 | **996** | <0.3 | 74 | 36 | 267 |
| | 5-10 cm | 14100 | <0.4 | 9.3 | 138 | 0.9 | 1.18 | 23800 | 26 | 33 | 185 | 21900 | **238** | 8930 | 434 | 4.7 | **1090** | <0.3 | 72 | 35 | 265 |
| | 10-20 cm | 14600 | <0.4 | 7.6 | 135 | 0.9 | 1.03 | 17000 | 27 | 33 | 161 | 20100 | **228** | 6660 | 431 | 3.8 | **1040** | <0.3 | 52 | 34 | 237 |
| | 10-20 cm | 16200 | <0.4 | 8.9 | 167 | 1 | 1.24 | 17900 | 29 | 34 | 203 | 21400 | **269** | 6870 | 468 | 4.0 | **1120** | <0.3 | 60 | 38 | 273 |
| | 10-20 cm | 16400 | <0.4 | 10.7 | 160 | 1 | 1.38 | 20600 | 31 | 38 | 208 | 23800 | **258** | 8080 | 504 | 4.6 | **1300** | <0.3 | 66 | 39 | 294 |
| 2292471 (Back yard) | 0-5 cm | 15100 | <0.4 | 6.5 | 140 | 1 | 1.17 | 18500 | 25 | 25 | 113 | 18600 | **207** | 6960 | 386 | 4.1 | **712** | <0.3 | 64 | 38 | 221 |
| | 0-5 cm | 15200 | <0.4 | 7.4 | 132 | 0.9 | 1.23 | 17700 | 24 | 26 | 117 | 19000 | 188 | 6840 | 395 | 4.0 | **725** | <0.3 | 62 | 37 | 202 |
| | 0-5 cm | 16700 | <0.4 | 8.3 | 143 | 1 | 1.57 | 19500 | 30 | 29 | 123 | 20600 | 205 | 7480 | 412 | 4.3 | **734** | <0.3 | 68 | 39 | 227 |
| | 5-10 cm | 16200 | <0.4 | 7.3 | 137 | 1 | 1.13 | 18700 | 25 | 27 | 114 | 19600 | 188 | 6960 | 386 | 4.0 | **726** | <0.3 | 65 | 38 | 202 |
| | 5-10 cm | 16200 | <0.4 | 6.9 | 132 | 1 | 1.19 | 17500 | 24 | 27 | 120 | 20300 | 176 | 6650 | 390 | 3.9 | **768** | <0.3 | 61 | 39 | 186 |
| | 5-10 cm | 17600 | <0.4 | 8.2 | 143 | 1 | 1.45 | 19000 | 28 | 29 | 126 | 21600 | 184 | 7350 | 407 | 4.2 | **825** | <0.3 | 69 | 42 | 212 |
| | 10-20 cm | 19600 | <0.4 | 7.5 | 143 | 1.1 | 1.22 | 15700 | 28 | 27 | 114 | 23400 | 191 | 6770 | 461 | 3.9 | **814** | <0.3 | 58 | 43 | 187 |
| | 10-20 cm | 18100 | <0.4 | 7.1 | 136 | 1.1 | 1.14 | 16900 | 26 | 29 | 125 | 22500 | 161 | 6770 | 459 | 3.7 | **908** | <0.3 | 58 | 41 | 177 |
| | 10-20 cm | 21200 | <0.4 | 8.9 | 164 | 1.2 | 1.50 | 20500 | 31 | 34 | 146 | 24900 | 191 | 8030 | 478 | 4.3 | **966** | <0.3 | 72 | 47 | 223 |
| 2292472 (Back yard) | 0-5 cm | 16500 | <0.4 | 3.7 | 97 | 0.8 | 0.49 | 15300 | 31 | 15 | 49 | 20000 | 61 | 6380 | 501 | 3.8 | **291** | <0.3 | 40 | 31 | 116 |
| | 5-10 cm | 19500 | <0.4 | 3.1 | 98 | 0.9 | 0.38 | 23100 | 23 | 14 | 34 | 22700 | 50 | 8040 | 564 | 3.5 | **166** | <0.3 | 46 | 35 | 86 |
| | 10-20 cm | 21300 | <0.4 | 5.5 | 127 | 1 | 0.54 | 28600 | 27 | 21 | 71 | 27000 | 73 | 8600 | 651 | 3.8 | **446** | <0.3 | 66 | 39 | 155 |
| 2292473 (Front yard) | 0-5 cm | 19500 | <0.4 | 5.2 | 130 | 0.9 | 0.92 | 11700 | 26 | 29 | 135 | 22600 | 140 | 6270 | 584 | 3.6 | **906** | <0.3 | 45 | 37 | 282 |
| | 5-10 cm | 22600 | <0.4 | 4.5 | 128 | 1 | 0.82 | 9220 | 27 | 28 | 139 | 24500 | 120 | 5830 | 662 | 3.5 | **765** | <0.3 | 41 | 40 | 208 |
| | 10-20 cm | 19800 | <0.4 | 7.0 | 127 | 0.9 | 0.99 | 12600 | 25 | 32 | 193 | 23300 | 140 | 5880 | 537 | 3.7 | **1050** | <0.3 | 56 | 37 | 234 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292474 (Front yard) | 0-5 cm | 24400 | <0.4 | 10.9 | 232 | 1.2 | 1.34 | 17400 | 32 | 44 | 225 | 30700 | **324** | 7700 | 450 | 3.7 | **1880** | <0.3 | 56 | 42 | 407 |
| | 5-10 cm | 24500 | <0.4 | 15.6 | 264 | **1.3** | 1.50 | 19800 | 34 | 45 | 257 | 34600 | **365** | 8050 | 481 | 4.0 | **2290** | <0.3 | 62 | 41 | 451 |
| | 10-20 cm | 22100 | 0.4 | 18.2 | 267 | 1.2 | 1.45 | 26500 | 30 | 40 | 224 | 35700 | **413** | 7810 | 461 | 4.1 | **2440** | 0.53 | 74 | 38 | 504 |
| 2292475 (Back yard) | 0-5 cm | 10200 | <0.4 | 1.6 | 75 | 0.4 | 0.44 | 9860 | 11 | 6 | 15 | 9890 | 33 | 3340 | 170 | 2.7 | 87 | <0.3 | 23 | 20 | 87 |
| | 5-10 cm | 10600 | <0.4 | 2.0 | 174 | 0.5 | 0.42 | 10200 | 12 | 7 | 18 | 11200 | 37 | 3150 | 192 | 2.7 | 144 | <0.3 | 24 | 22 | 82 |
| | 10-20 cm | 16000 | <0.4 | 3.6 | 956 | 0.8 | 0.46 | 20500 | 20 | 11 | 34 | 17300 | 86 | 5970 | 316 | 3.4 | **232** | <0.3 | 49 | 30 | 113 |
| 2292476 (Front yard) | 0-5 cm | 20700 | <0.4 | 4.9 | 136 | 0.9 | 0.80 | 23400 | 27 | 33 | 143 | 24000 | 183 | 9760 | 419 | 3.9 | **1020** | <0.3 | 55 | 37 | 220 |
| | 5-10 cm | 23900 | <0.4 | 6.2 | 150 | 1.1 | 0.81 | 23300 | 27 | 32 | 145 | 25800 | 172 | 9490 | 417 | 3.8 | **1100** | <0.3 | 56 | 40 | 218 |
| | 10-20 cm | 19900 | <0.4 | 6.7 | 130 | 1 | 0.69 | 27900 | 24 | 30 | 134 | 25000 | 138 | 10400 | 459 | 3.7 | **1100** | <0.3 | 58 | 35 | 198 |
| 2292477 (Back yard) | 0-5 cm | 22300 | 5.7 | 12.7 | 246 | 1.2 | 1.54 | 13500 | 39 | 38 | 253 | 34800 | **847** | 5840 | 504 | 4.1 | **1910** | 0.30 | 59 | 40 | 565 |
| | 5-10 cm | 21900 | 11.3 | 13.0 | 253 | 1.2 | 1.50 | 13300 | 37 | 36 | 223 | 34500 | **960** | 5890 | 496 | 4.0 | **1810** | 0.38 | 58 | 38 | 507 |
| | 10-20 cm | 23200 | 9.6 | 16.3 | 372 | **1.3** | 1.76 | 17600 | 41 | 43 | **331** | 38700 | 1170 | 6440 | 502 | 4.3 | **2540** | 0.82 | 77 | 39 | 643 |
| 2292478 (Front yard) | 0-5 cm | 27000 | <0.4 | 6.3 | 164 | 1.2 | 0.98 | 15000 | 32 | 38 | 173 | 25600 | 156 | 7240 | 371 | 4.0 | **1380** | <0.3 | 58 | 45 | 240 |
| | 5-10 cm | 29000 | <0.4 | 6.8 | 173 | 1.2 | 0.99 | 13300 | 32 | 39 | 170 | 26800 | 169 | 7000 | 379 | 3.7 | **1410** | <0.3 | 57 | 45 | 242 |
| | 10-20 cm | 25900 | <0.4 | 11.2 | 193 | 1.2 | 1.17 | 16400 | 34 | 47 | 259 | 31000 | 187 | 7200 | 469 | 4.2 | **2570** | <0.3 | 57 | 41 | 310 |
| 2292479 (Back yard) | 0-5 cm | 17200 | 0.9 | 16.7 | 264 | **1.4** | 1.69 | 18500 | 29 | 50 | 295 | 28900 | **299** | 5280 | 418 | 4.0 | **2620** | 1.10 | 115 | 36 | 579 |
| | 5-10 cm | 18900 | 0.5 | 21.0 | 378 | **1.9** | 1.84 | 24300 | 33 | 50 | **367** | 29000 | **387** | 5210 | 423 | 4.4 | **2970** | 0.95 | 199 | 37 | 750 |
| | 10-20 cm | 14400 | 1.3 | 17.0 | 420 | **1.8** | 1.47 | 30300 | 28 | 41 | **377** | 26900 | **483** | 5090 | 372 | 4.4 | **2630** | 0.34 | 219 | 30 | 733 |
| 2292480 (Front yard) | 0-5 cm | 21400 | <0.4 | 5.2 | 117 | 1 | 0.65 | 16800 | 25 | 24 | 94 | 22400 | 75 | 8500 | 378 | 3.7 | **786** | <0.3 | 44 | 38 | 147 |
| | 5-10 cm | 23300 | <0.4 | 4.5 | 127 | 1.1 | 0.61 | 16500 | 27 | 24 | 91 | 23600 | 73 | 8790 | 404 | 3.7 | **739** | <0.3 | 43 | 40 | 144 |
| | 10-20 cm | 23000 | <0.4 | 4.6 | 125 | 1 | 0.68 | 15600 | 26 | 28 | 107 | 24600 | 84 | 8490 | 409 | 3.7 | **956** | <0.3 | 41 | 39 | 152 |
| 2292481 (Back yard) | 0-5 cm | 18000 | <0.4 | 5.4 | 113 | 0.9 | 0.72 | 13400 | 23 | 20 | 83 | 18600 | 75 | 5940 | 257 | 3.1 | **677** | <0.3 | 60 | 35 | 164 |
| | 5-10 cm | 21700 | <0.4 | 6.7 | 128 | 1.1 | 0.89 | 16600 | 28 | 24 | 100 | 21600 | 89 | 6740 | 296 | 3.4 | **793** | <0.3 | 77 | 39 | 193 |
| | 10-20 cm | 19100 | <0.4 | 6.6 | 125 | 1 | 0.81 | 19800 | 25 | 23 | 104 | 20100 | 85 | 7080 | 288 | 3.5 | **811** | <0.3 | 77 | 35 | 189 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292482 (Front yard) | 0-5 cm | 17000 | <0.4 | 8.6 | 112 | 1 | 0.80 | 13700 | 24 | 49 | 181 | 23600 | 93 | 6400 | 440 | 3.5 | **1700** | 0.47 | 46 | 36 | 208 |
| | 0-5 cm | 17300 | <0.4 | 8.3 | 117 | 1 | 0.86 | 14100 | 26 | 50 | 184 | 24800 | 101 | 6700 | 465 | 3.7 | **1800** | 0.35 | 46 | 37 | 219 |
| | 0-5 cm | 21900 | <0.4 | 8.4 | 143 | 1.2 | 0.93 | 15400 | 30 | 48 | 182 | 25900 | 106 | 7540 | 495 | 4.0 | **1680** | <0.3 | 53 | 49 | 238 |
| | 5-10 cm | 24400 | <0.4 | 8.5 | 146 | **1.3** | 0.88 | 14100 | 32 | 50 | 185 | 28200 | 92 | 7660 | 481 | 3.6 | **1800** | <0.3 | 47 | 45 | 208 |
| | 5-10 cm | 26400 | <0.4 | 6.3 | 155 | **1.4** | 0.79 | 14200 | 32 | 43 | 161 | 27800 | 88 | 8090 | 493 | 3.9 | **1390** | <0.3 | 58 | 51 | 210 |
| | 5-10 cm | 32800 | <0.4 | 4.8 | 183 | **1.7** | 0.70 | 14100 | 38 | 39 | 134 | 30800 | 82 | 9530 | 475 | 3.8 | **1160** | <0.3 | 53 | 60 | 191 |
| | 10-20 cm | 20200 | <0.4 | 8.7 | 132 | 1.2 | 0.72 | 17700 | 26 | 38 | 150 | 27400 | 77 | 7370 | 500 | 3.6 | **1520** | <0.3 | 48 | 39 | 180 |
| | 10-20 cm | 27000 | <0.4 | 5.4 | 156 | **1.4** | 0.67 | 16100 | 32 | 35 | 129 | 28700 | 80 | 8680 | 480 | 3.7 | **1180** | <0.3 | 52 | 52 | 177 |
| | 10-20 cm | 28600 | <0.4 | 6.2 | 168 | **1.6** | 0.67 | 18000 | 32 | 38 | 141 | 28700 | 75 | 9090 | 496 | 3.9 | **1200** | <0.3 | 56 | 54 | 177 |
| 2292483 (Back yard) | 0-5 cm | 25400 | <0.4 | 7.8 | 162 | **1.4** | 0.79 | 14300 | 31 | 28 | 108 | 23000 | 87 | 6380 | 369 | 3.6 | **977** | <0.3 | 65 | 46 | 186 |
| | 0-5 cm | 24800 | <0.4 | 6.9 | 164 | **1.3** | 0.77 | 13600 | 28 | 27 | 109 | 22900 | 96 | 6180 | 367 | 3.6 | **930** | <0.3 | 63 | 45 | 187 |
| | 0-5 cm | 25800 | <0.4 | 7.4 | 167 | **1.4** | 0.81 | 14000 | 31 | 28 | 111 | 23900 | 89 | 6390 | 381 | 4.0 | **929** | <0.3 | 64 | 47 | 188 |
| | 5-10 cm | 27900 | <0.4 | 8.9 | 197 | **1.6** | 0.77 | 14700 | 32 | 29 | 110 | 24400 | 86 | 6730 | 374 | 3.7 | **963** | <0.3 | 68 | 49 | 187 |
| | 5-10 cm | 26800 | <0.4 | 6.8 | 168 | **1.4** | 0.80 | 14600 | 30 | 29 | 113 | 23900 | 89 | 6530 | 380 | 3.5 | **976** | <0.3 | 65 | 48 | 191 |
| | 5-10 cm | 26300 | <0.4 | 7.9 | 164 | **1.4** | 0.76 | 12800 | 30 | 28 | 107 | 23700 | 83 | 6380 | 362 | 3.4 | **942** | <0.3 | 61 | 48 | 183 |
| | 10-20 cm | 28500 | <0.4 | 9.6 | 183 | **1.6** | 0.79 | 16300 | 32 | 27 | 107 | 25200 | 95 | 6860 | 367 | 3.9 | **998** | <0.3 | 72 | 49 | 187 |
| | 10-20 cm | 24700 | <0.4 | 8.0 | 159 | **1.3** | 0.68 | 14700 | 28 | 24 | 97 | 22300 | 75 | 6300 | 331 | 3.4 | **834** | <0.3 | 61 | 44 | 169 |
| | 10-20 cm | 27100 | <0.4 | 9.6 | 171 | **1.4** | 0.76 | 15100 | 32 | 26 | 104 | 24400 | 82 | 6650 | 355 | 3.6 | **930** | <0.3 | 69 | 48 | 178 |
| 2292484 (Front yard) | 0-5 cm | 19700 | <0.4 | 8.7 | 122 | 1.1 | 0.87 | 17700 | 28 | 22 | 89 | 21500 | 134 | 9220 | 423 | 5.5 | **629** | <0.3 | 62 | 43 | 182 |
| | 5-10 cm | 21900 | <0.4 | 6.1 | 130 | 1.2 | 0.83 | 14800 | 29 | 24 | 89 | 23600 | 125 | 8250 | 454 | 5.3 | **648** | <0.3 | 61 | 47 | 179 |
| | 10-20 cm | 20500 | <0.4 | 6.0 | 115 | 1.1 | 0.80 | 13800 | 27 | 24 | 89 | 23100 | 114 | 7200 | 480 | 5.5 | **738** | <0.3 | 61 | 43 | 163 |
| 2292485 (Back yard) | 0-5 cm | 15400 | <0.4 | 17.8 | 181 | 0.9 | 1.93 | 22600 | 32 | 23 | 131 | 20500 | **313** | 9490 | 312 | 6.2 | **765** | <0.3 | 89 | 36 | 375 |
| | 5-10 cm | 17800 | <0.4 | 15.1 | 202 | **1.3** | 2.20 | 24500 | 32 | 26 | 139 | 22000 | **372** | 8540 | 338 | 6.0 | **871** | <0.3 | 95 | 40 | 390 |
| | 10-20 cm | 28400 | <0.4 | 11.2 | 228 | **1.6** | 1.81 | 25600 | 39 | 27 | 220 | 28900 | **259** | 11700 | 383 | 6.1 | **703** | <0.3 | 104 | 56 | 316 |
| 2292486 (Front yard) | 0-5 cm | 14300 | <0.4 | 9.3 | 160 | 1 | 1.20 | 32500 | 26 | 29 | 145 | 21000 | **277** | 14200 | 458 | 6.7 | **1010** | <0.3 | 79 | 37 | 274 |
| | 5-10 cm | 17300 | <0.4 | 9.3 | 178 | 1.1 | 1.33 | 35700 | 28 | 31 | 151 | 23400 | **271** | 16300 | 490 | 6.7 | **1010** | <0.3 | 80 | 42 | 279 |
| | 10-20 cm | 17500 | <0.4 | 10.9 | 185 | 1 | 1.04 | 45500 | 26 | 31 | 145 | 24300 | **406** | 20300 | 491 | 7.0 | **1300** | <0.3 | 84 | 38 | 253 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292487 (Back yard) | 0-5 cm | 14300 | <0.4 | 2.2 | 83 | 0.8 | 1.26 | 9400 | 21 | 17 | 58 | 18200 | 92 | 5700 | 630 | 4.9 | **207** | <0.3 | 40 | 34 | 155 |
| | 5-10 cm | 13500 | <0.4 | 1.4 | 54 | 0.7 | 0.62 | 4650 | 17 | 12 | 34 | 18300 | 44 | 4210 | 542 | 4.1 | 99 | <0.3 | 24 | 31 | 75 |
| | 10-20 cm | 12900 | <0.4 | 1.5 | 46 | 0.7 | 0.44 | 2880 | 15 | 10 | 20 | 17400 | 25 | 3630 | 587 | 3.4 | 46 | <0.3 | 17 | 28 | 52 |
| 2292488 (Front yard) | 0-5 cm | 19500 | <0.4 | 7.7 | 143 | 1.1 | 1.10 | 16000 | 28 | 28 | 129 | 22100 | 168 | 7320 | 374 | 5.7 | **970** | <0.3 | 62 | 44 | 232 |
| | 5-10 cm | 22600 | <0.4 | 7.8 | 159 | 1.2 | 1.17 | 17300 | 30 | 30 | 130 | 24600 | 160 | 8220 | 411 | 5.7 | **968** | <0.3 | 64 | 49 | 232 |
| | 10-20 cm | 27100 | <0.4 | 7.0 | 172 | **1.4** | 0.85 | 27700 | 33 | 30 | 130 | 29700 | 125 | 11200 | 466 | 6.1 | **917** | <0.3 | 85 | 53 | 187 |
| 2292489 (Back yard) | 0-5 cm | 26300 | <0.4 | 8.3 | 192 | **1.4** | 1.13 | 22600 | 35 | 24 | 104 | 26300 | 153 | 8940 | 492 | 5.7 | **644** | <0.3 | 82 | 54 | 246 |
| | 5-10 cm | 28700 | <0.4 | 8.8 | 200 | **1.5** | 1.98 | 22600 | 36 | 23 | 89 | 29700 | 148 | 10600 | 471 | 6.0 | **586** | <0.3 | 73 | 57 | 658 |
| | 10-20 cm | 33900 | <0.4 | 6.0 | 249 | **1.7** | 0.96 | 20600 | 41 | 27 | 95 | 32800 | 158 | 10400 | 541 | 5.8 | **637** | <0.3 | 76 | 64 | 256 |
| 2292490 (Front yard) | 0-5 cm | 21900 | <0.4 | 6.7 | 157 | **1.3** | 1.87 | 12700 | 41 | 32 | 134 | 32400 | 178 | 5870 | 521 | 5.8 | **953** | <0.3 | 57 | 47 | 334 |
| | 0-5 cm | 19100 | <0.4 | 7.9 | 140 | 1.2 | 1.87 | 14600 | 38 | 31 | 140 | 30300 | 182 | 6060 | 502 | 5.8 | **926** | <0.3 | 60 | 41 | 339 |
| | 0-5 cm | 21400 | <0.4 | 8.0 | 150 | **1.3** | 2.23 | 14400 | 38 | 30 | 132 | 29700 | 169 | 6160 | 562 | 5.9 | **921** | <0.3 | 59 | 44 | 303 |
| | 5-10 cm | 24200 | <0.4 | 7.3 | 149 | **1.4** | 1.67 | 11900 | 43 | 31 | 130 | 30500 | 152 | 6060 | 497 | 5.8 | **971** | <0.3 | 54 | 50 | 284 |
| | 5-10 cm | 20100 | <0.4 | 7.6 | 129 | 1.2 | 1.60 | 12000 | 36 | 29 | 125 | 28900 | 147 | 5680 | 467 | 5.5 | **918** | <0.3 | 51 | 41 | 278 |
| | 5-10 cm | 22000 | <0.4 | 7.3 | 140 | **1.3** | 1.64 | 11900 | 37 | 29 | 128 | 28600 | 150 | 5780 | 491 | 5.8 | **907** | <0.3 | 52 | 44 | 272 |
| | 10-20 cm | 22200 | <0.4 | 13.7 | 180 | **1.6** | 2.38 | 22700 | 43 | 36 | 220 | 48900 | **264** | 5950 | 736 | 7.2 | **1200** | 0.40 | 106 | 39 | 561 |
| | 10-20 cm | 22200 | <0.4 | 13.8 | 172 | **1.6** | 2.34 | 21400 | 40 | 34 | 174 | 37800 | **224** | 6050 | 671 | 6.4 | **1230** | <0.3 | 93 | 42 | 436 |
| | 10-20 cm | 20500 | <0.4 | 12.3 | 167 | **1.5** | 2.11 | 20700 | 36 | 32 | 164 | 34600 | **227** | 5680 | 588 | 6.0 | **1250** | <0.3 | 90 | 39 | 387 |
| 2292491 (Back yard) | 0-5 cm | 23200 | <0.4 | 7.5 | 154 | **1.3** | 0.74 | 30200 | 30 | 21 | 79 | 26200 | 93 | 14600 | 523 | 6.2 | **484** | <0.3 | 87 | 47 | 169 |
| | 0-5 cm | 20000 | <0.4 | 8.6 | 146 | 1.2 | 1.02 | 23900 | 28 | 22 | 92 | 25600 | 115 | 11500 | 484 | 6.0 | **617** | <0.3 | 85 | 42 | 207 |
| | 0-5 cm | 20200 | <0.4 | 9.5 | 147 | 1.2 | 1.02 | 26000 | 28 | 23 | 98 | 24800 | 128 | 11900 | 469 | 5.8 | **677** | <0.3 | 97 | 43 | 212 |
| | 5-10 cm | 19800 | <0.4 | 8.3 | 147 | 1.2 | 0.76 | 35900 | 26 | 21 | 84 | 25300 | 91 | 15300 | 536 | 6.6 | **641** | <0.3 | 100 | 40 | 185 |
| | 5-10 cm | 24700 | <0.4 | 6.2 | 157 | **1.3** | 0.74 | 36000 | 31 | 21 | 83 | 28600 | 113 | 13900 | 503 | 5.6 | **553** | <0.3 | 104 | 46 | 163 |
| | 5-10 cm | 21700 | <0.4 | 8.8 | 150 | **1.3** | 0.97 | 24900 | 29 | 23 | 91 | 26700 | 99 | 11100 | 512 | 6.1 | **648** | <0.3 | 95 | 45 | 186 |
| | 10-20 cm | 20600 | <0.4 | 7.9 | 141 | 1.2 | 0.60 | 37000 | 26 | 18 | 68 | 25200 | 78 | 14300 | 494 | 6.5 | **396** | <0.3 | 98 | 40 | 128 |
| | 10-20 cm | 22900 | <0.4 | 8.4 | 163 | **1.3** | 0.87 | 25100 | 30 | 24 | 94 | 28100 | 113 | 11600 | 583 | 6.0 | **662** | <0.3 | 92 | 46 | 191 |
| | 10-20 cm | 26600 | <0.4 | 7.0 | 160 | **1.4** | 0.80 | 33200 | 33 | 21 | 77 | 30000 | 91 | 12500 | 504 | 5.7 | **629** | <0.3 | 118 | 50 | na |

## Table 6-3: Results of Chemical Analysis (μg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292492 (Front yard) | 0-5 cm | 14100 | <0.4 | 3.5 | 61 | 0.6 | 0.47 | 4800 | 15 | 11 | 38 | 13000 | 56 | 2390 | 160 | 3.8 | **296** | <0.3 | 21 | 26 | 83 |
|  | 5-10 cm | 13400 | <0.4 | 2.4 | 52 | 0.5 | 0.41 | 3760 | 13 | 10 | 30 | 11600 | 47 | 1970 | 137 | 3.3 | **221** | <0.3 | 17 | 24 | 68 |
|  | 10-20 cm | 14900 | <0.4 | 2.8 | 49 | 0.5 | 0.40 | 3090 | 13 | 9 | 25 | 12600 | 39 | 1890 | 131 | 3.2 | 192 | <0.3 | 14 | 25 | 61 |
| 2292493 (Back yard) | 0-5 cm | 17400 | <0.4 | 17.9 | 191 | **1.3** | 1.42 | 30200 | 27 | 27 | 160 | 22800 | **219** | 12400 | 354 | 6.4 | **1080** | <0.3 | 180 | 42 | 267 |
|  | 5-10 cm | 14600 | <0.4 | 13.9 | 149 | 1.1 | 1.20 | 23500 | 24 | 25 | 139 | 19900 | **207** | 10300 | 308 | 6.3 | **1010** | <0.3 | 134 | 38 | 242 |
| 2292494 (Front yard) | 0-5 cm | 20500 | <0.4 | 6.7 | 127 | 1.1 | 1.09 | 10200 | 29 | 23 | 96 | 23500 | 120 | 5910 | 495 | 4.9 | **726** | <0.3 | 41 | 44 | 209 |
|  | 5-10 cm | 20400 | <0.4 | 4.8 | 122 | 1.1 | 0.90 | 9670 | 27 | 22 | 87 | 23400 | 101 | 5720 | 526 | 5.0 | **662** | <0.3 | 39 | 43 | 181 |
|  | 10-20 cm | 24000 | <0.4 | 9.8 | 139 | 1.2 | 0.57 | 14000 | 29 | 23 | 101 | 27400 | 106 | 7280 | 492 | 1.7 | **786** | <0.3 | 52 | 46 | 206 |
| 2292495 (Back yard) | 0-5 cm | 16900 | 0.4 | 11.8 | 114 | 0.8 | 0.68 | 8500 | 22 | 19 | 95 | 18800 | 116 | 3810 | 308 | 1.7 | **637** | <0.3 | 54 | 36 | 212 |
|  | 5-10 cm | 17400 | 0.5 | 13.2 | 118 | 0.8 | 0.67 | 8190 | 22 | 20 | 97 | 19400 | 113 | 3860 | 309 | 1.4 | **702** | <0.3 | 54 | 37 | 196 |
|  | 10-20 cm | 19000 | <0.4 | 13.9 | 124 | 0.8 | 0.65 | 8020 | 23 | 19 | 87 | 19400 | 114 | 4060 | 311 | 1.4 | **620** | <0.3 | 56 | 39 | 185 |
| 2292496 (Front yard) | 0-5 cm | 26000 | 0.8 | 13.5 | 177 | 1.2 | 1.22 | 13700 | 36 | 38 | 150 | 27300 | **221** | 7140 | 437 | 2.3 | **1070** | <0.3 | 68 | 56 | 374 |
|  | 5-10 cm | 27700 | 0.7 | 14.5 | 197 | **1.3** | 1.32 | 12800 | 36 | 40 | 156 | 29200 | **210** | 7350 | 744 | 2.3 | **1110** | <0.3 | 67 | 58 | 351 |
|  | 10-20 cm | 21900 | 0.6 | **27.7** | 153 | 1 | 1.36 | 15300 | 30 | 30 | 129 | 26500 | **270** | 6930 | 372 | 2.2 | **1070** | <0.3 | 64 | 50 | 338 |
| 2292497 (Back yard) | 0-5 cm | 15300 | 1.3 | 14.4 | 200 | 0.8 | 1.51 | 21600 | 26 | 24 | 127 | 20100 | **489** | 8590 | 309 | 2.1 | **1100** | <0.3 | 86 | 37 | 419 |
|  | 5-10 cm | 15400 | 3.1 | 17.3 | 298 | 0.8 | 1.51 | 24400 | 29 | 26 | 204 | 20400 | 1200 | 8050 | 339 | 2.0 | **1770** | <0.3 | 94 | 37 | 556 |
|  | 10-20 cm | 20100 | 1.4 | 18.8 | 258 | 1.1 | 1.33 | 22300 | 30 | 25 | 145 | 23800 | **386** | 7840 | 329 | 2.3 | **1180** | <0.3 | 126 | 44 | 407 |
| 2292498 (Front yard) | 0-5 cm | 27100 | 0.7 | 12.0 | 187 | **1.3** | 0.95 | 14800 | 40 | 36 | 161 | 27800 | **221** | 7780 | 495 | 2.3 | **1180** | <0.3 | 58 | 55 | 289 |
|  | 5-10 cm | 24900 | 0.5 | 11.4 | 186 | 1.2 | 1.00 | 13100 | 38 | 32 | 146 | 26500 | 194 | 7020 | 452 | 2.0 | **1170** | <0.3 | 52 | 51 | 248 |
|  | 10-20 cm | 25000 | 0.5 | 14.1 | 177 | 1.2 | 0.69 | 18700 | 35 | 34 | 166 | 29000 | **246** | 8000 | 477 | 2.1 | **1600** | <0.3 | 66 | 50 | 268 |
| 2292499 (Back yard) | 0-5 cm | 30600 | <0.4 | 19.3 | 189 | **1.3** | 1.20 | 12400 | 37 | 24 | 109 | 24300 | 123 | 6350 | 484 | 2.1 | **640** | <0.3 | 100 | 58 | 220 |
|  | 5-10 cm | 30800 | 0.6 | 20.0 | 189 | **1.3** | 1.24 | 11400 | 36 | 23 | 106 | 24700 | 122 | 5960 | 496 | 2.1 | **624** | <0.3 | 102 | 58 | 207 |
|  | 10-20 cm | 33000 | 0.7 | 21.1 | 198 | **1.4** | 1.23 | 13400 | 37 | 23 | 110 | 26500 | 126 | 6380 | 449 | 1.9 | **653** | <0.3 | 117 | 60 | 200 |
| 2292500 (Front yard) | 0-5 cm | 31100 | 0.5 | 9.3 | 185 | **1.3** | 1.04 | 17000 | 39 | 32 | 137 | 24300 | 194 | 8270 | 379 | 2.1 | **1060** | <0.3 | 62 | 58 | 238 |
|  | 5-10 cm | 32300 | 0.5 | 10.5 | 199 | **1.3** | 1.43 | 12500 | 40 | 33 | 143 | 24100 | **210** | 7790 | 371 | 2.0 | **1060** | <0.3 | 59 | 59 | 245 |
|  | 10-20 cm | 33000 | 0.5 | 11.2 | 189 | **1.3** | 0.97 | 12800 | 38 | 30 | 135 | 26400 | 171 | 8170 | 419 | 2.0 | **1220** | <0.3 | 63 | 58 | 214 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292501 (Back yard) | 0-5 cm | 37700 | <0.4 | 8.4 | 225 | **1.7** | 1.13 | 14300 | 46 | 28 | 109 | 27000 | 124 | 8530 | 359 | 2.2 | **642** | <0.3 | 87 | 68 | 227 |
| | 5-10 cm | 40000 | 0.4 | 8.7 | 243 | **1.7** | 1.29 | 16500 | 46 | 26 | 100 | 29300 | 118 | 9320 | 395 | 2.1 | **616** | <0.3 | 92 | 70 | 207 |
| | 10-20 cm | 34900 | 0.5 | 7.5 | 237 | **1.6** | 0.88 | 21100 | 42 | 23 | 68 | 33200 | 93 | 10700 | 518 | 2.0 | **340** | <0.3 | 89 | 62 | 196 |
| 2292502 (Front yard) | 0-5 cm | 25200 | 0.8 | 17.0 | 177 | **1.3** | 0.81 | 15200 | 36 | 36 | 177 | 28400 | **204** | 7630 | 409 | 2.3 | **1460** | <0.3 | 78 | 51 | 340 |
| | 5-10 cm | 27300 | 0.8 | 19.1 | 204 | **1.4** | 0.80 | 15000 | 38 | 38 | 177 | 31900 | **210** | 8350 | 467 | 2.1 | **1620** | <0.3 | 79 | 54 | 342 |
| | 10-20 cm | 25700 | 0.9 | **26.7** | 190 | **1.3** | 0.75 | 18300 | 35 | 39 | 207 | 31600 | 197 | 8300 | 456 | 2.4 | **1980** | <0.3 | 90 | 51 | 300 |
| 2292503 (Back yard) | 0-5 cm | 19900 | 1.5 | 18.2 | 317 | 1.1 | 1.05 | 24800 | 36 | 35 | 173 | 28300 | **259** | 8080 | 410 | 2.7 | **1390** | 0.40 | 134 | 48 | 492 |
| | 5-10 cm | 23000 | 1.8 | **26.1** | 380 | **1.3** | 1.36 | 24800 | 43 | 40 | 208 | 31700 | **280** | 8240 | 457 | 2.7 | **1630** | 0.40 | 160 | 54 | 575 |
| | 10-20 cm | 23300 | 1.9 | 25.0 | 384 | **1.4** | 1.29 | 26300 | 40 | 36 | 215 | 31600 | **268** | 8030 | 454 | 2.8 | **1480** | <0.3 | 178 | 54 | 540 |
| 2292504 (Back yard) | 0-5 cm | 20700 | 1.7 | 18.3 | 251 | **1.3** | 2.78 | 26600 | 40 | **68** | 269 | 32300 | **330** | 10200 | 576 | 3.1 | **1970** | 0.70 | 114 | 55 | **892** |
| | 5-10 cm | 22400 | 1.6 | 18.6 | 263 | **1.4** | 1.98 | 25500 | 38 | 47 | 237 | 33900 | **236** | 9380 | 540 | 2.8 | **2010** | <0.3 | 128 | 52 | 727 |
| | 10-20 cm | 22800 | 1.7 | 17.7 | 295 | **1.6** | 1.13 | 30800 | 35 | 37 | 279 | 31500 | **213** | 10000 | 497 | 2.5 | **1840** | <0.3 | 153 | 49 | 561 |
| 2292505 (Front yard) | 0-5 cm | 18600 | 0.4 | 12.1 | 197 | 0.9 | 0.95 | 29100 | 28 | 24 | 115 | 23100 | 152 | 9220 | 548 | 2.2 | **801** | 0.40 | 82 | 39 | 343 |
| | 5-10 cm | 19800 | 0.7 | 15.7 | 198 | 1 | 1.10 | 23100 | 30 | 31 | 154 | 26200 | 183 | 9340 | 502 | 2.3 | **1300** | <0.3 | 73 | 44 | 343 |
| | 10-20 cm | 19600 | 1.2 | 14.8 | 194 | 1 | 0.84 | 22600 | 30 | 34 | 241 | 28300 | **269** | 9270 | 552 | 2.1 | **1470** | 0.50 | 74 | 45 | 327 |
| 2292506 (Back yard) | 0-5 cm | 26500 | <0.4 | 8.1 | 195 | **1.3** | 1.42 | 19800 | 35 | 23 | 113 | 25200 | 138 | 8930 | 349 | 5.5 | **683** | <0.3 | 90 | 50 | 296 |
| | 5-10 cm | 22700 | <0.4 | 9.7 | 188 | 1.1 | 0.75 | 44600 | 30 | 21 | 95 | 26200 | 117 | 19100 | 440 | 2.1 | **560** | <0.3 | 131 | 45 | 228 |
| | 10-20 cm | 28600 | <0.4 | 8.1 | 204 | **1.6** | 1.52 | 27500 | 38 | 24 | 103 | 25800 | 113 | 13800 | 396 | 6.4 | **641** | <0.3 | 107 | 52 | 280 |
| 2292507 (Front yard) | 0-5 cm | 18300 | <0.4 | 10.0 | 152 | 1.1 | 1.41 | 23400 | 31 | 32 | 148 | 24900 | **248** | 10300 | 484 | 6.0 | **1120** | <0.3 | 67 | 42 | 330 |
| | 5-10 cm | 21500 | <0.4 | 13.4 | 194 | **1.3** | 1.63 | 23400 | 37 | 39 | 196 | 29200 | **302** | 10700 | 526 | 6.4 | **1640** | <0.3 | 73 | 45 | 369 |
| | 10-20 cm | 21700 | <0.4 | 14.5 | 183 | **1.3** | 1.58 | 23300 | 33 | 37 | 176 | 30300 | **260** | 10000 | 511 | 6.0 | **1700** | <0.3 | 83 | 44 | 350 |
| 2292508 (Back yard) | 0-5 cm | 25500 | <0.4 | 9.5 | 180 | **1.4** | 1.49 | 14200 | 36 | 25 | 102 | 26500 | 160 | 7600 | 430 | 5.6 | **603** | <0.3 | 59 | 52 | 256 |
| | 5-10 cm | 26800 | <0.4 | 7.2 | 168 | **1.4** | 1.38 | 12300 | 35 | 25 | 93 | 27100 | 122 | 8030 | 432 | 5.3 | **663** | <0.3 | 51 | 53 | 216 |
| | 10-20 cm | 26900 | <0.4 | 9.8 | 178 | **1.6** | 1.48 | 14000 | 36 | 23 | 99 | 26000 | 143 | 7920 | 404 | 5.4 | **608** | <0.3 | 61 | 53 | 226 |
| 2292509 (Front yard) | 0-5 cm | 13200 | <0.4 | 4.3 | 82 | 0.7 | 0.63 | 9870 | 21 | 15 | 51 | 16900 | 94 | 4810 | 392 | 4.6 | **290** | <0.3 | 32 | 31 | 140 |
| | 5-10 cm | 13700 | <0.4 | 5.4 | 99 | 0.7 | 0.62 | 14500 | 20 | 16 | 54 | 17900 | 125 | 5350 | 410 | 5.0 | **352** | 0.80 | 40 | 32 | 150 |
| | 10-20 cm | 15000 | <0.4 | 5.9 | 111 | 0.8 | 0.78 | 12900 | 25 | 22 | 74 | 20900 | 126 | 5830 | 462 | 5.0 | **678** | 0.40 | 44 | 36 | 190 |

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## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292510 (Back yard) | 0-5 cm | 13700 | <0.4 | 6.7 | 149 | 0.7 | 1.00 | 15400 | 23 | 17 | 70 | 15800 | **260** | 6430 | 329 | 5.2 | **429** | <0.3 | 53 | 30 | 276 |
| | 5-10 cm | 14100 | <0.4 | 6.7 | 165 | 0.8 | 1.11 | 17500 | 24 | 18 | 75 | 17500 | **313** | 7060 | 380 | 5.4 | **474** | <0.3 | 61 | 33 | 311 |
| | 10-20 cm | 14200 | <0.4 | 7.9 | 160 | 0.8 | 1.18 | 18200 | 24 | 18 | 86 | 17900 | **320** | 7110 | 360 | 5.8 | **461** | <0.3 | 64 | 32 | 302 |
| 2292511 (Back yard) | 0-5 cm | 16000 | <0.4 | 5.7 | 94 | 0.6 | 0.44 | 12400 | 23 | 16 | 49 | 20100 | 74 | 6480 | 405 | 5.6 | **357** | <0.3 | 47 | 40 | 136 |
| | 5-10 cm | 17500 | <0.4 | 5.3 | 95 | 0.7 | 0.35 | 14600 | 24 | 17 | 48 | 21300 | 63 | 7230 | 455 | 5.6 | **337** | <0.3 | 63 | 44 | 125 |
| | 10-20 cm | 11800 | <0.4 | 4.4 | 61 | 0.4 | 0.29 | 18500 | 20 | 17 | 49 | 20400 | 47 | 7200 | 415 | 5.5 | **421** | 0.30 | 60 | 42 | 141 |
| 2292512 (Front yard) | 0-5 cm | 16500 | <0.4 | 8.9 | 132 | 0.9 | 0.89 | 28400 | 27 | 33 | 174 | 21500 | **214** | 12700 | 472 | 6.1 | **1010** | <0.3 | 91 | 41 | 314 |
| | 5-10 cm | 18500 | <0.4 | 10.5 | 139 | 1 | 0.92 | 29700 | 28 | 36 | 211 | 23200 | **277** | 13000 | 490 | 6.6 | **1120** | <0.3 | 96 | 44 | 416 |
| | 10-20 cm | 22200 | 0.5 | 11.6 | 144 | 1.1 | 0.77 | 24300 | 30 | 33 | 153 | 27000 | **247** | 10500 | 573 | 7.4 | **1090** | <0.3 | 88 | 47 | 297 |
| 2292513 (Back yard) | 0-5 cm | 15300 | 6.8 | 15.3 | 446 | 0.7 | 2.10 | 15100 | 28 | 25 | **1100** | 21500 | 1350 | 5380 | 534 | 6.8 | **847** | <0.3 | 77 | 39 | **1210** |
| | 5-10 cm | 18400 | 2.5 | **26.7** | 284 | 1.3 | 1.84 | 21000 | 34 | 38 | 277 | 30500 | **352** | 6310 | 539 | 8.4 | **1930** | 0.40 | 131 | 43 | 583 |
| | 10-20 cm | 15900 | 1.5 | 15.3 | 187 | 0.7 | 1.13 | 14000 | 27 | 26 | 201 | 22800 | **251** | 5020 | 480 | 6.8 | **980** | <0.3 | 69 | 38 | 370 |
| 2292514 (Front yard) | 0-5 cm | 17400 | 1.0 | 14.4 | 197 | 1.1 | 1.17 | 35400 | 32 | **51** | 281 | 26300 | **290** | 12800 | 686 | 8.0 | **1590** | <0.3 | 130 | 46 | 409 |
| | 5-10 cm | 16100 | 1.0 | 15.2 | 190 | 1.1 | 1.19 | 35000 | 29 | 49 | **323** | 26100 | **302** | 12400 | 753 | 8.2 | **1600** | <0.3 | 173 | 45 | 396 |
| | 10-20 cm | 15000 | 1.2 | 16.3 | 174 | 0.9 | 0.77 | 31800 | 30 | 47 | 255 | 31200 | **269** | 9950 | 769 | 8.3 | **2160** | 0.40 | 110 | 40 | 356 |
| 2292515 (Back yard) | 0-5 cm | 17100 | 3.5 | 17.2 | 511 | **2.2** | 1.43 | 62100 | 32 | 44 | 226 | 34500 | **414** | 11000 | 2030 | 9.7 | **1950** | 0.80 | 151 | 39 | 643 |
| | 5-10 cm | 14600 | 4.5 | 21.3 | 534 | **1.8** | 1.55 | 52900 | 34 | 39 | 222 | 42100 | **587** | 7950 | 3880 | 11.4 | **2050** | 1.20 | 169 | 33 | 685 |
| | 10-20 cm | 14400 | 3.2 | 20.0 | 397 | **1.6** | 1.57 | 45500 | 35 | 28 | 175 | 37200 | **461** | 7260 | 2500 | 10.2 | **1330** | 0.50 | 179 | 32 | 544 |
| 2292516 (Front yard) | 0-5 cm | 19000 | <0.4 | 8.4 | 124 | 0.8 | 0.52 | 15100 | 26 | 22 | 100 | 21400 | 137 | 6390 | 381 | 5.9 | **668** | <0.3 | 55 | 42 | 177 |
| | 5-10 cm | 21400 | <0.4 | 9.5 | 139 | 1 | 0.53 | 15400 | 29 | 26 | 120 | 22700 | 132 | 7020 | 399 | 6.4 | **735** | <0.3 | 55 | 45 | 185 |
| | 10-20 cm | 21300 | <0.4 | 8.6 | 129 | 0.9 | 0.47 | 15500 | 28 | 28 | 132 | 23400 | 116 | 7030 | 440 | 6.9 | **772** | <0.3 | 50 | 46 | 175 |
| 2292517 (Front yard) | 0-5 cm | 26100 | 0.7 | 11.0 | 170 | 1.2 | 0.55 | 14900 | 35 | 43 | 199 | 28900 | 197 | 8410 | 522 | 8.1 | **1090** | <0.3 | 61 | 60 | 545 |
| | 5-10 cm | 29700 | <0.4 | 9.1 | 172 | **1.3** | 0.54 | 9960 | 38 | 32 | 128 | 30900 | 128 | 7980 | 554 | 7.9 | **688** | <0.3 | 47 | 61 | 301 |
| | 10-20 cm | 27800 | 1.4 | 12.0 | 256 | **1.3** | 0.62 | 16700 | 39 | 34 | 152 | 33100 | **363** | 9610 | 571 | 8.8 | **1210** | <0.3 | 62 | 55 | 590 |
| 2292518 (Back yard) | 0-5 cm | 14900 | <0.4 | 5.8 | 90 | 0.6 | 0.61 | 8930 | 20 | 16 | 62 | 16600 | 164 | 4030 | 324 | 5.4 | **380** | <0.3 | 34 | 35 | 173 |
| | 5-10 cm | 15100 | <0.4 | 5.7 | 87 | 0.5 | 0.60 | 7720 | 20 | 16 | 59 | 16000 | 184 | 3510 | 296 | 5.3 | **368** | <0.3 | 30 | 35 | 155 |
| | 10-20 cm | 16900 | <0.4 | 6.6 | 113 | 0.7 | 0.72 | 9260 | 21 | 16 | 61 | 17000 | 162 | 4390 | 302 | 5.4 | **412** | <0.3 | 35 | 36 | 169 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292519 (Front yard) | 0-5 cm | 21400 | <0.4 | 8.6 | 142 | 0.9 | 0.31 | 19300 | 28 | 35 | 193 | 22200 | 121 | 9310 | 418 | 6.6 | **1270** | <0.3 | 102 | 48 | 189 |
| | 5-10 cm | 23000 | 0.6 | 11.6 | 146 | 1.1 | 0.03 | 25400 | 30 | **60** | **356** | 21900 | 101 | 11000 | 351 | 6.9 | **2690** | <0.3 | 116 | 49 | 161 |
| | 10-20 cm | 23800 | <0.4 | 10.0 | 166 | 1.1 | 0.17 | 23900 | 32 | 39 | 217 | 24000 | 126 | 10300 | 497 | 7.4 | **1420** | <0.3 | 161 | 51 | 193 |
| 2292520 (Back yard) | 0-5 cm | 18500 | <0.4 | 10.0 | 135 | 0.9 | 0.03 | 24800 | 25 | 41 | 254 | 22500 | 94 | 9250 | 397 | 6.4 | **1870** | <0.3 | 100 | 40 | 174 |
| | 5-10 cm | 18600 | <0.4 | 10.2 | 133 | 0.9 | 0.03 | 27100 | 25 | 44 | 274 | 22800 | 90 | 10300 | 383 | 6.7 | **1990** | <0.3 | 111 | 40 | 163 |
| | 10-20 cm | 20800 | <0.4 | 9.3 | 158 | 1 | 0.14 | 33400 | 27 | 31 | 198 | 25400 | 92 | 10700 | 496 | 7.2 | **1260** | <0.3 | 152 | 43 | 188 |
| 2292521 (Front yard) | 0-5 cm | 11600 | 2.3 | 10.2 | 163 | 0.7 | 0.92 | 25100 | 22 | 25 | 141 | 19000 | **370** | 8240 | 444 | 6.0 | **713** | <0.3 | 89 | 29 | 316 |
| | 5-10 cm | 12300 | 1.1 | 12.0 | 174 | 0.7 | 0.93 | 25100 | 23 | 27 | 165 | 19500 | **444** | 7700 | 476 | 6.3 | **843** | <0.3 | 90 | 31 | 316 |
| | 10-20 cm | 11300 | <0.4 | 10.2 | 114 | 0.6 | 0.49 | 25000 | 21 | 33 | 222 | 18400 | **221** | 9660 | 496 | 6.2 | **928** | <0.3 | 72 | 30 | 197 |
| 2292522 (Back yard) | 0-5 cm | 17100 | <0.4 | 6.4 | 115 | 0.9 | 0.50 | 23100 | 23 | 14 | 41 | 21400 | 60 | 8860 | 385 | 6.3 | **202** | <0.3 | 96 | 37 | 130 |
| | 5-10 cm | 29900 | <0.4 | 7.9 | 188 | **1.4** | 0.42 | 29400 | 37 | 21 | 45 | 34600 | 68 | 12500 | 563 | 8.2 | **208** | <0.3 | 144 | 57 | 136 |
| | 10-20 cm | 33100 | <0.4 | 8.2 | 197 | **1.8** | 0.29 | 35700 | 38 | 21 | 45 | 37600 | 73 | 12800 | 609 | 8.7 | **203** | <0.3 | 166 | 58 | 135 |
| 2292523 (Front yard) | 0-5 cm | 19900 | 0.8 | 13.5 | 201 | 1.1 | 1.26 | 16100 | 34 | 44 | 248 | 23400 | **222** | 7220 | 385 | 6.6 | **1430** | <0.3 | 86 | 45 | 358 |
| | 5-10 cm | 25800 | 0.7 | 15.7 | 230 | **1.3** | 1.48 | 16000 | 40 | **51** | **319** | 25000 | **246** | 7650 | 406 | 7.0 | **1590** | <0.3 | 99 | 51 | 365 |
| | 10-20 cm | 24200 | 1.0 | 15.5 | 219 | 1.2 | 1.13 | 14500 | 36 | 36 | 208 | 27100 | 199 | 6780 | 387 | 7.1 | **1600** | <0.3 | 105 | 44 | 305 |
| 2292524 (Back yard) | 0-5 cm | 20200 | 0.9 | 19.9 | 164 | 1.1 | 1.07 | 15300 | 30 | 30 | 170 | 25500 | 160 | 5550 | 379 | 6.5 | **1280** | <0.3 | 147 | 43 | 347 |
| | 5-10 cm | 19200 | 1.1 | 19.1 | 155 | 1.1 | 0.89 | 13800 | 28 | 29 | 158 | 24100 | 148 | 5320 | 347 | 6.0 | **1260** | <0.3 | 135 | 41 | 304 |
| | 10-20 cm | 18700 | 2.4 | 20.5 | 204 | 1.1 | 1.00 | 17200 | 31 | 32 | 212 | 29700 | **228** | 5980 | 367 | 6.8 | **1620** | 0.30 | 153 | 39 | 381 |
| 2292525 (Front yard) | 0-5 cm | 11000 | 1.1 | 11.1 | 173 | 0.8 | 1.29 | 29800 | 27 | 38 | 249 | 21400 | **244** | 11500 | 470 | 5.5 | **1110** | <0.3 | 73 | 33 | 314 |
| | 5-10 cm | 12500 | 1.3 | 16.5 | 203 | 0.9 | 1.86 | 38200 | 33 | 50 | **507** | 23700 | **316** | 14100 | 534 | 6.4 | **1690** | 0.60 | 92 | 34 | 351 |
| | 10-20 cm | 11800 | 1.7 | 15.4 | 347 | 0.9 | 1.70 | 49900 | 31 | 47 | **393** | 24100 | **317** | 14300 | 492 | 6.4 | **1680** | 0.70 | 113 | 31 | 433 |
| 2292526 (Back yard) | 0-5 cm | 15800 | <0.4 | 6.4 | 156 | 0.8 | 0.63 | 14700 | 26 | 15 | 70 | 19300 | 164 | 7020 | 368 | 5.1 | **310** | <0.3 | 61 | 35 | 208 |
| | 5-10 cm | 17200 | <0.4 | 6.7 | 174 | 0.9 | 0.70 | 18700 | 29 | 17 | 74 | 20400 | 192 | 8370 | 384 | 5.0 | **318** | <0.3 | 78 | 37 | 229 |
| | 10-20 cm | 16200 | 0.9 | 7.6 | 212 | 0.9 | 1.10 | 25400 | 33 | 17 | 97 | 22700 | **252** | 10200 | 431 | 5.8 | **366** | <0.3 | 106 | 37 | 306 |
| 2292527 (Front yard) | 0-5 cm | 10600 | 0.7 | 9.8 | 191 | 0.7 | 0.93 | 26800 | 20 | 26 | 153 | 19500 | **328** | 9420 | 337 | 5.9 | **972** | 0.30 | 92 | 32 | 283 |
| | 5-10 cm | 10400 | 0.5 | 9.6 | 184 | 0.8 | 0.91 | 26600 | 19 | 24 | 141 | 18000 | **314** | 8690 | 340 | 5.1 | **816** | <0.3 | 88 | 30 | 267 |
| | 10-20 cm | 13200 | 1.4 | 13.7 | 267 | 0.9 | 1.23 | 36500 | 35 | 30 | 184 | 24300 | **458** | 9620 | 394 | 6.7 | **1260** | 0.50 | 124 | 34 | 379 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292528 (Back yard) | 0-5 cm | 14200 | 0.9 | 7.2 | 135 | 0.8 | 0.71 | 11800 | 51 | 21 | 94 | 18600 | 174 | 4950 | 307 | 5.3 | **585** | <0.3 | 62 | 32 | 339 |
| | 5-10 cm | 16500 | 0.6 | 7.0 | 134 | 0.9 | 0.64 | 11200 | 34 | 19 | 89 | 17900 | 168 | 4910 | 286 | 5.3 | **536** | <0.3 | 62 | 33 | 247 |
| | 10-20 cm | 17800 | 0.6 | 7.9 | 170 | 1.1 | 1.00 | 11000 | 25 | 17 | 81 | 17700 | 169 | 4700 | 315 | 5.5 | **399** | <0.3 | 82 | 34 | **1760** |
| 2292529 (Front yard) | 0-5 cm | 12700 | <0.4 | 5.5 | 100 | 0.6 | 0.52 | 7030 | 18 | 14 | 55 | 17100 | 156 | 3760 | 361 | 4.7 | **273** | <0.3 | 31 | 29 | 185 |
| | 5-10 cm | 14200 | <0.4 | 5.8 | 109 | 0.6 | 0.57 | 7510 | 28 | 16 | 66 | 18200 | 174 | 4020 | 396 | 5.0 | **349** | <0.3 | 36 | 32 | 193 |
| | 10-20 cm | 13500 | <0.4 | 9.4 | 152 | 0.7 | 0.76 | 12700 | 24 | 25 | 125 | 21900 | **314** | 5570 | 452 | 5.9 | **784** | <0.3 | 88 | 35 | 316 |
| 2292530 (Back yard) | 0-5 cm | 13700 | <0.4 | 7.3 | 110 | 0.7 | 0.62 | 8580 | 18 | 13 | 71 | 13400 | 99 | 3230 | 189 | 4.0 | **356** | <0.3 | 53 | 29 | 148 |
| | 5-10 cm | 16700 | <0.4 | 9.9 | 150 | 0.9 | 0.76 | 10000 | 21 | 15 | 83 | 15400 | 139 | 3590 | 226 | 4.9 | **482** | <0.3 | 64 | 34 | 184 |
| | 10-20 cm | 18900 | <0.4 | 13.8 | 170 | 1 | 0.84 | 13000 | 26 | 18 | 102 | 20300 | 177 | 4900 | 289 | 5.1 | **641** | <0.3 | 74 | 39 | 234 |
| 2292531 (Front yard) | 0-5 cm | 18900 | <0.4 | 9.7 | 168 | 1.1 | 0.79 | 15700 | 30 | 28 | 131 | 22800 | **246** | 6640 | 399 | 5.3 | **687** | <0.3 | 66 | 45 | 266 |
| | 0-5 cm | 17700 | <0.4 | 7.9 | 156 | 1 | 0.75 | 16900 | 26 | 27 | 136 | 22200 | 200 | 7000 | 404 | 5.7 | **650** | <0.3 | 66 | 42 | 223 |
| | 0-5 cm | 17300 | 0.7 | 9.8 | 162 | 1.1 | 0.85 | 15900 | 27 | 31 | 163 | 21900 | **246** | 6820 | 376 | 6.2 | **844** | <0.3 | 64 | 42 | 257 |
| | 5-10 cm | 21600 | <0.4 | 9.2 | 186 | 1.2 | 0.75 | 15300 | 31 | 29 | 129 | 24600 | **282** | 7020 | 417 | 5.7 | **656** | <0.3 | 67 | 49 | 259 |
| | 5-10 cm | 19900 | 0.5 | 8.5 | 169 | 1.1 | 0.76 | 16600 | 29 | 31 | 145 | 23700 | **210** | 7340 | 452 | 6.4 | **762** | <0.3 | 68 | 46 | 237 |
| | 5-10 cm | 21400 | 0.5 | 9.8 | 181 | **1.3** | 0.76 | 13800 | 31 | 31 | 141 | 23900 | **223** | 6740 | 372 | 6.3 | **720** | <0.3 | 63 | 48 | 247 |
| | 10-20 cm | 21500 | <0.4 | 7.9 | 212 | 1.2 | 0.51 | 20000 | 29 | 24 | 82 | 26700 | **287** | 7530 | 426 | 5.9 | **470** | <0.3 | 69 | 47 | 227 |
| | 10-20 cm | 19900 | 0.7 | 8.4 | 205 | 1.2 | 0.82 | 20800 | 29 | 30 | 138 | 23000 | **284** | 7930 | 364 | 5.9 | **772** | <0.3 | 75 | 44 | 245 |
| | 10-20 cm | 21100 | <0.4 | 8.3 | 190 | **1.3** | 0.76 | 13800 | 29 | 29 | 136 | 23300 | **228** | 6700 | 367 | 5.9 | **895** | <0.3 | 63 | 46 | 242 |
| 2292532 (Back yard) | 0-5 cm | 11400 | 2.1 | 20.0 | 263 | 0.9 | 1.59 | 25100 | 27 | 30 | 220 | 24800 | **442** | 5550 | 432 | 6.4 | **1400** | 1.10 | 121 | 37 | 527 |
| | 0-5 cm | 8830 | 2.1 | 14.6 | 194 | 0.7 | 1.07 | 19200 | 21 | 24 | 168 | 19600 | **364** | 4660 | 339 | 5.6 | **1070** | 0.70 | 88 | 30 | 399 |
| | 0-5 cm | 9530 | 2.0 | 16.0 | 205 | 0.8 | 1.38 | 19400 | 26 | 25 | 167 | 21100 | **386** | 4730 | 349 | 6.0 | **1030** | 1.00 | 92 | 31 | 429 |
| | 5-10 cm | 11700 | 2.4 | 22.9 | 287 | 0.9 | 1.42 | 24300 | 28 | 32 | 232 | 25800 | **480** | 5300 | 446 | 6.3 | **1420** | 1.30 | 113 | 37 | 573 |
| | 5-10 cm | 10300 | 2.1 | 18.7 | 247 | 0.8 | 1.32 | 21900 | 24 | 26 | 202 | 21200 | **409** | 4630 | 378 | 6.4 | **1170** | 1.10 | 101 | 32 | 475 |
| | 5-10 cm | 11700 | 2.5 | 22.7 | 288 | 0.9 | 1.57 | 24000 | 27 | 31 | 211 | 30200 | **542** | 5360 | 451 | 7.9 | **1320** | 1.60 | 107 | 36 | 540 |
| | 10-20 cm | 9630 | 1.8 | 20.0 | 269 | 0.7 | 1.11 | 23600 | 23 | 23 | 189 | 22700 | **406** | 4950 | 361 | 5.6 | **1030** | 1.10 | 109 | 35 | 439 |
| | 10-20 cm | 9490 | 2.0 | 20.0 | 360 | 0.8 | 1.19 | 23500 | 26 | 22 | 190 | 20900 | **637** | 4380 | 376 | 6.2 | **1060** | 1.20 | 111 | 31 | 452 |
| | 10-20 cm | 8990 | 2.2 | 16.8 | 211 | 0.8 | 1.09 | 20100 | 20 | 23 | 157 | 20100 | **343** | 4440 | 347 | 6.0 | **1110** | 0.90 | 92 | 29 | 404 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292533 (Front yard) | 0-5 cm | 11700 | 0.4 | 10.6 | 132 | 0.8 | 0.65 | 26900 | 20 | 33 | 198 | 18600 | 183 | 9920 | 360 | 5.3 | **1150** | <0.3 | 73 | 29 | 242 |
| | 5-10 cm | 10900 | 0.4 | 11.2 | 129 | 0.8 | 0.58 | 27200 | 21 | 39 | 205 | 20700 | 189 | 9530 | 367 | 5.8 | **1640** | 0.40 | 68 | 30 | 264 |
| | 10-20 cm | 12300 | 0.5 | 14.4 | 170 | 0.9 | 0.69 | 26600 | 22 | 39 | 219 | 21800 | **233** | 9490 | 385 | 6.2 | **1600** | 0.70 | 83 | 31 | 341 |
| 2292534 (Back yard) | 0-5 cm | 11000 | 0.8 | 18.5 | 256 | 0.9 | 1.14 | 21200 | 37 | 24 | 152 | 19200 | **303** | 5970 | 297 | 6.0 | **997** | <0.3 | 102 | 31 | 451 |
| | 5-10 cm | 15500 | 1.6 | 23.5 | 345 | **1.3** | 1.59 | 26000 | 30 | 30 | 201 | 23000 | **444** | 6890 | 365 | 6.6 | **1260** | 0.40 | 142 | 37 | 650 |
| | 10-20 cm | 12000 | 0.9 | 18.9 | 232 | 1 | 1.19 | 24900 | 22 | 22 | 151 | 19000 | **302** | 5990 | 280 | 5.7 | **1020** | 0.30 | 124 | 30 | 502 |
| 2292535 (Front yard) | 0-5 cm | 15400 | 0.4 | 8.4 | 106 | 0.8 | 0.53 | 19900 | 25 | 26 | 157 | 19200 | 135 | 8270 | 357 | 5.6 | **877** | <0.3 | 72 | 33 | 171 |
| | 5-10 cm | 15300 | <0.4 | 8.3 | 99 | 0.8 | 0.40 | 18400 | 23 | 23 | 130 | 19100 | 110 | 7200 | 343 | 5.8 | **812** | <0.3 | 66 | 32 | 150 |
| | 10-20 cm | 15100 | <0.4 | 16.8 | 149 | 1 | 1.68 | 38600 | 33 | 71 | **524** | 26400 | **344** | 16000 | 542 | 5.6 | **2330** | 2.10 | 91 | 37 | 319 |
| 2292536 (Back yard) | 0-5 cm | 18600 | <0.4 | 16.6 | 350 | 1.2 | 2.03 | 24000 | 42 | 33 | 211 | 25900 | **400** | 7320 | 379 | 4.5 | **1420** | 1.10 | 122 | 44 | 566 |
| | 5-10 cm | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 10-20 cm | 16000 | <0.4 | 10.8 | 156 | 1 | 1.22 | 24900 | 29 | 32 | 187 | 23200 | **225** | 10300 | 488 | 4.6 | **1010** | <0.3 | 71 | 37 | 311 |
| 2292537 (Front yard) | 0-5 cm | 20600 | <0.4 | 12.9 | 185 | 1.2 | 1.40 | 29000 | 31 | 34 | 197 | 27100 | **289** | 10900 | 545 | 4.7 | **1130** | <0.3 | 82 | 43 | 382 |
| | 5-10 cm | 20200 | <0.4 | 13.6 | 195 | 1.2 | 1.40 | 29300 | 32 | 35 | 200 | 27100 | **267** | 11200 | 565 | 4.8 | **1160** | <0.3 | 81 | 42 | 386 |
| | 10-20 cm | 19000 | <0.4 | 16.4 | 181 | 1.1 | 1.47 | 26300 | 31 | 37 | 219 | 27900 | **309** | 9920 | 541 | 4.7 | **1400** | <0.3 | 87 | 41 | 364 |
| 2292538 (Back yard) | 0-5 cm | 20900 | <0.4 | 17.1 | 224 | **1.3** | 2.51 | 20200 | 38 | **54** | **304** | 27700 | **525** | 7850 | 440 | 4.7 | **1770** | 0.90 | 125 | 50 | 603 |
| | 5-10 cm | 22000 | <0.4 | 17.6 | 236 | **1.3** | 2.28 | 16900 | 37 | 42 | 237 | 31000 | **438** | 7050 | 429 | 4.4 | **1770** | 0.50 | 107 | 44 | 527 |
| | 10-20 cm | 20100 | <0.4 | 16.4 | 240 | 1.2 | 1.56 | 22500 | 32 | 26 | 155 | 27600 | **467** | 7470 | 413 | 4.3 | **1020** | <0.3 | 121 | 40 | 363 |
| 2292539 (Front yard) | 0-5 cm | 20700 | <0.4 | 6 | 122 | 1 | 1.00 | 10700 | 29 | 23 | 83 | 26300 | 94 | 6330 | 481 | 5 | **666** | <0.3 | 38 | 45 | 187 |
| | 5-10 cm | 19700 | <0.4 | 5.0 | 112 | 1 | 0.75 | 8140 | 26 | 20 | 67 | 23700 | 79 | 5540 | 467 | 4.7 | **544** | <0.3 | 32 | 42 | 152 |
| | 10-20 cm | 19300 | <0.4 | 3.7 | 101 | 1 | 0.61 | 7260 | 25 | 16 | 48 | 22300 | 56 | 5430 | 437 | 4.4 | **388** | <0.3 | 28 | 40 | 126 |
| 2292540 (Back yard) | 0-5 cm | 20500 | <0.4 | 2.5 | 90 | 0.7 | 0.43 | 3180 | 25 | 9 | 15 | 17400 | 51 | 3310 | 165 | 3.3 | 110 | <0.3 | 27 | 36 | 80 |
| | 5-10 cm | 19700 | <0.4 | 1.1 | 78 | 0.7 | 0.29 | 1920 | 23 | 7 | 4 | 15800 | 31 | 2880 | 137 | 2.8 | 35 | <0.3 | 17 | 34 | 52 |
| | 10-20 cm | 21800 | <0.4 | 3.6 | 110 | 0.8 | 0.60 | 5120 | 28 | 14 | 43 | 19600 | 89 | 3890 | 230 | 4.2 | **282** | <0.3 | 35 | 39 | 129 |
| 2292541 (Front yard) | 0-5 cm | 20000 | <0.4 | 14.5 | 165 | 1 | 1.89 | 24700 | 33 | **82** | **337** | 34800 | 171 | 9600 | 604 | 4.4 | **4240** | 1.45 | 84 | 39 | 398 |
| | 5-10 cm | 23000 | <0.4 | 21.7 | 182 | 1.2 | 2.43 | 20000 | 38 | **115** | **477** | 45500 | **236** | 8730 | 781 | 4.6 | **5720** | 2.25 | 79 | 43 | 435 |
| | 10-20 cm | 22900 | 0.6 | 24.3 | 173 | 1.1 | 2.15 | 18500 | 46 | **100** | **474** | 55200 | 176 | 8520 | 720 | 5.2 | **6630** | 2.45 | 75 | 41 | 518 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292542 (Back yard) | 0-5 cm | 18600 | <0.4 | 8.8 | 144 | 0.8 | 1.22 | 18700 | 27 | 26 | 137 | 22400 | 190 | 7620 | 503 | 3.7 | **1020** | <0.3 | 58 | 37 | 275 |
| | 5-10 cm | 19400 | <0.4 | 12.5 | 167 | 0.9 | 1.42 | 22600 | 29 | 28 | 175 | 23300 | **272** | 8800 | 469 | 3.7 | **1200** | <0.3 | 66 | 39 | 325 |
| | 10-20 cm | 18600 | 1.4 | 20.3 | 195 | 1 | 1.96 | 19800 | 36 | **64** | **339** | 37600 | **346** | 7310 | 511 | 4.4 | **3480** | 1.27 | 69 | 37 | 486 |
| 2292543 (Front yard) | 0-5 cm | 20500 | <0.4 | 6.2 | 127 | 1 | 0.82 | 17300 | 26 | 36 | 138 | 22600 | 102 | 9910 | 474 | 3.7 | **1440** | <0.3 | 55 | 41 | 179 |
| | 5-10 cm | 21600 | <0.4 | 6.8 | 128 | 1.1 | 0.80 | 18200 | 27 | 32 | 127 | 23400 | 92 | 10300 | 516 | 3.9 | **1240** | <0.3 | 53 | 42 | 164 |
| | 10-20 cm | 24600 | <0.4 | 6.8 | 150 | 1.2 | 0.81 | 24800 | 29 | 33 | 151 | 26100 | 109 | 13200 | 549 | 4.1 | **1410** | <0.3 | 71 | 46 | 179 |
| 2292544 (Back yard) | 0-5 cm | 20300 | <0.4 | 7.5 | 122 | 1 | 0.96 | 8050 | 29 | 35 | 142 | 26100 | 164 | 6060 | 486 | 3.4 | **1340** | <0.3 | 36 | 42 | 268 |
| | 5-10 cm | 22400 | <0.4 | 6.7 | 127 | 1.1 | 0.95 | 11100 | 31 | 35 | 146 | 28100 | 151 | 7810 | 497 | 3.7 | **1360** | <0.3 | 39 | 44 | 258 |
| | 10-20 cm | 20700 | 1.5 | 16.2 | 261 | 1.1 | 1.91 | 15500 | 47 | **61** | **326** | 39600 | **406** | 8040 | 566 | 4.2 | **3520** | 0.92 | 61 | 40 | 673 |
| 2292545 (Front yard) | 0-5 cm | 15900 | <0.4 | 14.0 | 166 | 0.9 | 1.24 | 23800 | 26 | 46 | 203 | 27100 | **219** | 10800 | 517 | 4.3 | **2410** | 0.55 | 166 | 32 | 406 |
| | 0-5 cm | 17700 | <0.4 | 12.7 | 164 | 1 | 1.12 | 22900 | 26 | 40 | 177 | 25600 | 194 | 11300 | 467 | 4.0 | **1910** | <0.3 | 157 | 35 | 346 |
| | 0-5 cm | 17600 | <0.4 | 13.8 | 181 | 1 | 1.20 | 24200 | 28 | 41 | 184 | 26700 | **216** | 11300 | 519 | 4.3 | **2060** | <0.3 | 351 | 35 | 397 |
| | 5-10 cm | 19200 | <0.4 | 15.7 | 184 | 1 | 1.35 | 25700 | 30 | **52** | 229 | 30900 | **271** | 11600 | 588 | 4.3 | **2790** | 0.52 | 189 | 38 | 456 |
| | 5-10 cm | 17800 | <0.4 | 17.6 | 183 | 1.1 | 1.39 | 26100 | 30 | **51** | 239 | 29300 | **243** | 11800 | 530 | 4.3 | **2790** | <0.3 | 200 | 35 | 454 |
| | 5-10 cm | 19700 | <0.4 | 13.4 | 178 | 1.1 | 1.21 | 23600 | 29 | 40 | 185 | 28200 | 197 | 11300 | 545 | 4.2 | **2010** | <0.3 | 198 | 39 | 375 |
| | 10-20 cm | 14500 | 0.8 | **27.2** | 271 | 0.9 | 2.22 | 22900 | 32 | **86** | **403** | 38000 | **698** | 8280 | 595 | 4.5 | **5370** | 2.71 | 208 | 31 | **901** |
| | 10-20 cm | 14600 | 0.9 | 24.2 | 265 | 0.9 | 2.15 | 26200 | 34 | **83** | **387** | 36600 | **515** | 9570 | 602 | 4.7 | **4700** | 2.26 | 247 | 32 | 793 |
| | 10-20 cm | 15900 | <0.4 | 23.3 | 235 | 1 | 1.81 | 24200 | 31 | **75** | **344** | 34700 | **412** | 8730 | 601 | 4.5 | **4190** | 2.21 | 247 | 33 | 699 |
| 2292546 (Back yard) | 0-5 cm | 13600 | <0.4 | **29.2** | 151 | 0.7 | 1.96 | 17200 | 25 | **61** | **310** | 32700 | 190 | 4900 | 517 | 4.0 | **3900** | 2.10 | 91 | 26 | 499 |
| | 0-5 cm | 13500 | 0.5 | **30.4** | 156 | 0.7 | 2.06 | 17700 | 26 | **70** | **362** | 37600 | **208** | 4930 | 582 | 4.1 | **4790** | 2.47 | 94 | 27 | 522 |
| | 0-5 cm | 14100 | 0.5 | **29.8** | 160 | 0.8 | 2.02 | 17900 | 28 | **66** | **336** | 35400 | **252** | 4870 | 547 | 4.4 | **4320** | 2.65 | 96 | 28 | 526 |
| | 5-10 cm | 13600 | <0.4 | **31.8** | 151 | 0.7 | 2.03 | 17700 | 28 | **68** | **333** | 36300 | 196 | 5020 | 542 | 4.2 | **4660** | 2.37 | 88 | 27 | 502 |
| | 5-10 cm | 13100 | <0.4 | **32.8** | 153 | 0.7 | 2.06 | 17000 | 26 | **68** | **346** | 35800 | 198 | 4570 | 547 | 4.3 | **4600** | 2.59 | 100 | 26 | 507 |
| | 5-10 cm | 12100 | 0.4 | **30.7** | 145 | 0.6 | 1.92 | 15700 | 24 | **63** | **323** | 32900 | **206** | 4160 | 514 | 3.9 | **4160** | 2.38 | 80 | 24 | 479 |
| | 10-20 cm | 14200 | 0.7 | **37.6** | 170 | 0.8 | 2.31 | 18900 | 29 | **74** | **370** | 39900 | **217** | 4890 | 601 | 4.3 | **5060** | 3.11 | 102 | 27 | 553 |
| | 10-20 cm | 14400 | 0.4 | **46.3** | 188 | 0.8 | 2.65 | 21500 | 30 | **74** | **428** | 37800 | **259** | 4880 | 626 | 4.4 | **4740** | 4.16 | 123 | 28 | 627 |
| | 10-20 cm | 13200 | 1.1 | **43.8** | 186 | 0.8 | 2.56 | 20000 | 32 | **89** | **469** | 42800 | **246** | 4600 | 634 | 4.6 | **6590** | 4.26 | 111 | 26 | 621 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292547 (Front yard) | 0-5 cm | 16500 | <0.4 | 21.1 | 146 | 1 | 1.74 | 16800 | 36 | **82** | **379** | 39600 | **239** | 7030 | 550 | 5.1 | **5090** | 4.09 | 58 | 35 | 486 |
| | 5-10 cm | 17300 | <0.4 | 24.6 | 141 | 1 | 1.73 | 19600 | 33 | **79** | **372** | 41600 | 182 | 8670 | 577 | 4.5 | **5420** | 3.46 | 56 | 36 | 458 |
| | 10-20 cm | 17300 | <0.4 | 22.8 | 137 | 1 | 1.74 | 19300 | 32 | **81** | **372** | 42800 | 181 | 8570 | 573 | 4.6 | **5630** | 2.86 | 56 | 37 | 454 |
| 2292548 (Back yard) | 0-5 cm | 13100 | 1.7 | **31.9** | 267 | 1 | 2.68 | 19600 | 36 | **112** | **548** | 47000 | **431** | 5550 | 631 | 4.8 | **7360** | 4.85 | 102 | 32 | 872 |
| | 5-10 cm | 13500 | 1.8 | **41.9** | 301 | 1 | 3.47 | 22300 | 42 | **109** | **546** | 53500 | **437** | 5580 | 719 | 5.3 | **7680** | 4.70 | 111 | 31 | **1090** |
| | 10-20 cm | 11700 | 2.4 | 24.9 | 283 | 0.9 | 2.08 | 20700 | 29 | **64** | **373** | 34500 | **339** | 4600 | 453 | 4.2 | **3730** | 2.97 | 111 | 27 | 727 |
| 2292549 (Front yard) | 0-5 cm | 34500 | <0.4 | 14.1 | 196 | **1.6** | 1.46 | 11300 | 41 | **59** | 292 | 26900 | 94 | 7940 | 343 | 3.9 | **2790** | <0.3 | 74 | 59 | 271 |
| | 5-10 cm | 36700 | <0.4 | 15.2 | 214 | **1.8** | 1.55 | 9480 | 44 | **57** | 295 | 29200 | 100 | 7150 | 361 | 3.8 | **2790** | <0.3 | 72 | 63 | 239 |
| | 10-20 cm | 20700 | <0.4 | 15.4 | 158 | 1 | 1.54 | 17700 | 32 | **63** | 287 | 34400 | **224** | 6200 | 487 | 4.2 | **3530** | 0.73 | 75 | 39 | 364 |
| 2292550 (Back yard) | 0-5 cm | 16400 | <0.4 | 13.3 | 256 | 1.2 | 1.41 | 18000 | 42 | 39 | 264 | 28800 | **228** | 4620 | 465 | 4.3 | **2030** | <0.3 | 133 | 33 | 503 |
| | 5-10 cm | 19100 | 0.8 | 12.9 | 268 | **1.3** | 1.50 | 16400 | 45 | 43 | 247 | 29200 | **246** | 4750 | 466 | 4.3 | **2190** | <0.3 | 132 | 39 | 502 |
| | 10-20 cm | 16100 | 1.0 | 22.5 | 408 | **1.9** | 2.21 | 22300 | 44 | **78** | **486** | 44000 | **429** | 5030 | 564 | 5.3 | **5000** | 2.13 | 232 | 38 | 670 |
| 2292551 (Front yard) | 0-5 cm | 15500 | <0.4 | 11.0 | 126 | 0.8 | 1.24 | 15600 | 26 | 49 | 202 | 28200 | 138 | 5630 | 458 | 4.0 | **2400** | 1.25 | 78 | 31 | 304 |
| | 5-10 cm | 18700 | <0.4 | 12.2 | 147 | 0.9 | 1.30 | 15800 | 28 | **54** | 267 | 31800 | 152 | 5350 | 454 | 4.1 | **2610** | 1.27 | 92 | 36 | 321 |
| | 10-20 cm | 18100 | <0.4 | 12.4 | 148 | 0.9 | 1.21 | 14800 | 28 | **51** | 237 | 35200 | 135 | 5450 | 466 | 3.9 | **2920** | 0.95 | 88 | 34 | 320 |
| 2292552 (Back yard) | 0-5 cm | 13600 | <0.4 | 9.0 | 147 | 0.7 | 0.96 | 10600 | 23 | 32 | 145 | 24100 | 144 | 4230 | 464 | 3.5 | **1560** | <0.3 | 39 | 28 | 320 |
| | 5-10 cm | 13400 | <0.4 | 8.9 | 133 | 0.7 | 0.90 | 10200 | 24 | 32 | 141 | 23600 | 130 | 4170 | 447 | 3.5 | **1530** | <0.3 | 36 | 28 | 308 |
| | 10-20 cm | 15300 | <0.4 | 13.8 | 187 | 0.8 | 1.48 | 15500 | 32 | **52** | 269 | 32300 | **216** | 5470 | 481 | 4.0 | **2870** | 1.18 | 59 | 31 | 505 |
| 2292553 (Front yard) | 0-5 cm | 14200 | 3.0 | 14.4 | 140 | 0.8 | 1.68 | 17900 | 28 | **73** | 289 | 30600 | **206** | 5760 | 493 | 4.3 | **3370** | 1.88 | 71 | 32 | 429 |
| | 5-10 cm | 12300 | 4.3 | 24.0 | 153 | 0.8 | 1.89 | 18300 | 26 | **85** | **382** | 36500 | **211** | 5090 | 579 | 4.3 | **4980** | 3.47 | 76 | 27 | 476 |
| | 10-20 cm | 12700 | 7.2 | **36.7** | 176 | 0.9 | 2.36 | 19400 | 28 | **84** | **471** | 40800 | **341** | 5290 | 650 | 4.6 | **5860** | 4.15 | 85 | 25 | 593 |
| 2292554 (Back yard) | 0-5 cm | 14200 | <0.4 | **28.6** | 112 | 0.7 | 1.65 | 10200 | 27 | **86** | **398** | 36800 | 121 | 3480 | 490 | 3.8 | **4940** | 3.74 | 88 | 30 | 341 |
| | 5-10 cm | 15200 | <0.4 | **27.8** | 116 | 0.8 | 1.43 | 9990 | 29 | **60** | **322** | 38200 | 106 | 3540 | 445 | 3.7 | **4180** | 2.58 | 98 | 27 | 327 |
| | 10-20 cm | 14900 | <0.4 | 13.1 | 93 | 0.6 | 0.79 | 7710 | 22 | 27 | 162 | 19600 | 55 | 3470 | 230 | 3.0 | **1650** | <0.3 | 73 | 28 | 155 |
| 2292555 (Back yard) | 0-5 cm | 14300 | 1.5 | 21.5 | 255 | 1 | 2.17 | 19900 | 34 | **68** | **408** | 36700 | **362** | 5310 | 526 | 4.2 | **4410** | 2.38 | 124 | 29 | 578 |
| | 5-10 cm | 14600 | 2.8 | **28.4** | 274 | 1.1 | 2.40 | 20100 | 35 | **78** | **462** | 42700 | **336** | 5420 | 575 | 4.3 | **5280** | 4.73 | 137 | 28 | 648 |
| | 10-20 cm | 14500 | 1.2 | **25.3** | 287 | 1.1 | 2.12 | 21200 | 33 | **65** | **420** | 38000 | **800** | 5170 | 522 | 4.2 | **4640** | 2.00 | 151 | 28 | 609 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292556 (Front yard) | 0-5 cm | 14400 | <0.4 | 6.7 | 97 | 0.7 | 0.66 | 15300 | 19 | 21 | 84 | 17400 | 66 | 7090 | 480 | 3.6 | **720** | <0.3 | 50 | 30 | 130 |
| | 5-10 cm | 17500 | <0.4 | 8.4 | 116 | 0.9 | 0.69 | 12200 | 21 | 24 | 99 | 19300 | 82 | 6580 | 464 | 3.4 | **861** | <0.3 | 46 | 34 | 133 |
| | 10-20 cm | 18100 | <0.4 | 5.6 | 123 | 0.9 | 0.62 | 17100 | 23 | 19 | 70 | 20700 | 150 | 7690 | 483 | 3.7 | **528** | <0.3 | 49 | 35 | 130 |
| 2292557 (Back yard) | 0-5 cm | 10700 | <0.4 | 8.0 | 83 | 0.5 | 0.65 | 16900 | 17 | 23 | 112 | 16800 | 53 | 4040 | 386 | 3.5 | **1040** | <0.3 | 54 | 22 | 141 |
| | 5-10 cm | 12000 | <0.4 | 11.4 | 81 | 0.6 | 0.81 | 8710 | 20 | 27 | 133 | 18400 | 65 | 3470 | 341 | 2.9 | **1270** | <0.3 | 43 | 24 | 156 |
| | 10-20 cm | 11800 | <0.4 | 18.5 | 95 | 0.6 | 1.06 | 8880 | 20 | 34 | 190 | 21200 | 82 | 3170 | 364 | 3.0 | **1680** | 0.43 | 56 | 24 | 210 |
| 2292558 (Front yard) | 0-5 cm | 8810 | <0.4 | 10.6 | 89 | 0.5 | 1.01 | 19000 | 18 | 30 | 133 | 18900 | 110 | 6280 | 392 | 3.6 | **1410** | <0.3 | 63 | 21 | 230 |
| | 0-5 cm | 9650 | <0.4 | 11.0 | 102 | 0.6 | 1.13 | 19000 | 18 | 36 | 162 | 21000 | 134 | 6660 | 441 | 3.8 | **1670** | 0.47 | 57 | 22 | 280 |
| | 0-5 cm | 9070 | <0.4 | 10.5 | 91 | 0.5 | 1.25 | 18400 | 18 | 32 | 143 | 19200 | 119 | 6650 | 415 | 3.9 | **1490** | 0.45 | 51 | 20 | 283 |
| | 5-10 cm | 9230 | <0.4 | 13.7 | 98 | 0.6 | 1.31 | 17400 | 20 | 41 | 189 | 22500 | 158 | 6450 | 422 | 3.9 | **2060** | 0.56 | 62 | 21 | 299 |
| | 5-10 cm | 10100 | <0.4 | 14.7 | 107 | 0.6 | 1.30 | 18000 | 19 | 44 | 200 | 24900 | 152 | 6310 | 459 | 3.8 | **2320** | 0.57 | 66 | 23 | 310 |
| | 5-10 cm | 9680 | <0.4 | 13.5 | 100 | 0.6 | 1.26 | 17300 | 19 | 42 | 198 | 23200 | 148 | 6580 | 413 | 4.0 | **2170** | 0.54 | 52 | 22 | 291 |
| | 10-20 cm | 8860 | 0.7 | 18.1 | 12[illegible] | 0.7 | 1.64 | 21900 | 27 | **53** | 254 | 29900 | **224** | 6470 | 471 | 4.3 | **2680** | 1.48 | 99 | 20 | 370 |
| | 10-20 cm | 8700 | <0.4 | 17.5 | 137 | 0.7 | 1.70 | 22600 | 21 | **61** | 276 | 33100 | **286** | 7090 | 493 | 4.5 | **3440** | 1.53 | 105 | 20 | 377 |
| | 10-20 cm | 10000 | <0.4 | 18.8 | 146 | 0.8 | 1.73 | 23900 | 23 | **57** | 273 | 31600 | **280** | 7750 | 504 | 4.3 | **2810** | 1.54 | 90 | 23 | 396 |
| 2292559 (Back yard) | 0-5 cm | 11800 | <0.4 | 9.5 | 90 | 0.6 | 1.35 | 15200 | 20 | 24 | 113 | 17600 | 118 | 5440 | 289 | 3.5 | **993** | <0.3 | 64 | 26 | 213 |
| | 0-5 cm | 12800 | <0.4 | 7.7 | 107 | 0.7 | 1.33 | 19100 | 21 | 24 | 122 | 17600 | **280** | 7920 | 343 | 3.8 | **978** | <0.3 | 75 | 25 | 239 |
| | 0-5 cm | 12700 | <0.4 | 8.4 | 96 | 0.7 | 1.29 | 17900 | 23 | 23 | 106 | 17400 | 119 | 7220 | 294 | 3.6 | **994** | <0.3 | 68 | 27 | 220 |
| | 5-10 cm | 12700 | <0.4 | 14.8 | 95 | 0.6 | 1.37 | 15900 | 23 | 25 | 115 | 18200 | 122 | 5870 | 316 | 3.6 | **948** | <0.3 | 76 | 27 | 208 |
| | 5-10 cm | 12800 | <0.4 | 6.8 | 105 | 0.6 | 1.22 | 21600 | 22 | 22 | 116 | 17600 | 138 | 8960 | 313 | 3.9 | **780** | <0.3 | 86 | 27 | 207 |
| | 5-10 cm | 12500 | <0.4 | 7.0 | 89 | 0.6 | 0.89 | 14100 | 48 | 20 | 142 | 15100 | 88 | 6080 | 263 | 3.5 | **751** | <0.3 | 86 | 28 | 421 |
| | 10-20 cm | 11200 | 0.4 | **29.3** | 150 | 0.6 | 3.07 | 12500 | 27 | **54** | 274 | 27400 | **428** | 4410 | 427 | 4.1 | **2610** | 1.60 | 100 | 24 | 429 |
| | 10-20 cm | 13800 | <0.4 | 18.1 | 139 | 0.8 | 1.81 | 15300 | 24 | 40 | 198 | 27900 | 193 | 5700 | 470 | 3.8 | **1970** | <0.3 | 100 | 27 | 348 |
| | 10-20 cm | 12300 | <0.4 | 15.4 | 125 | 0.7 | 1.51 | 15000 | 30 | 39 | 200 | 25400 | 146 | 4620 | 369 | 3.7 | **2060** | <0.3 | 102 | 26 | 438 |
| 2292560 (Front yard) | 0-5 cm | 8900 | <0.4 | 12.0 | 95 | 0.6 | 1.19 | 24800 | 20 | 36 | 159 | 28200 | 192 | 7430 | 505 | 4.7 | **1980** | <0.3 | 61 | 20 | 311 |
| | 5-10 cm | 9490 | 1.4 | 23.6 | 123 | 0.7 | 2.25 | 24900 | 29 | **71** | **333** | 48800 | **316** | 7610 | 753 | 4.8 | **4820** | 2.00 | 69 | 20 | 586 |
| | 10-20 cm | 7420 | <0.4 | 10.8 | 77 | 0.5 | 0.85 | 17700 | 15 | 25 | 153 | 21000 | 133 | 5320 | 377 | 3.2 | **1920** | <0.3 | 56 | 19 | 225 |

## Table 6-3: Results of Chemical Analysis (μg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292561 (Front yard) | 0-5 cm | 8090 | <0.4 | 9.2 | 96 | 0.5 | 1.80 | 23300 | 29 | 41 | 190 | 29700 | **225** | 9100 | 471 | 3.7 | **2150** | 0.50 | 51 | 22 | 410 |
| | 5-10 cm | 7200 | 1.1 | 17.5 | 103 | 0.6 | 2.06 | 25800 | 38 | **61** | 278 | 48000 | **256** | 8350 | 652 | 4.3 | **3350** | 1.40 | 60 | 20 | 647 |
| | 10-20 cm | 6850 | <0.4 | 17.9 | 93 | 0.6 | 1.82 | 24400 | 30 | 47 | 235 | 38300 | **212** | 7300 | 531 | 3.9 | **3130** | 0.80 | 54 | 17 | 466 |
| 2292562 (Back yard) | 0-5 cm | 10400 | 1.3 | 18.5 | 164 | 0.8 | 2.39 | 18900 | 30 | **70** | **334** | 39600 | **364** | 6620 | 545 | 4.2 | **4020** | 2.30 | 64 | 22 | 710 |
| | 5-10 cm | 8670 | 1.2 | 22.0 | 157 | 0.7 | 2.26 | 20700 | 29 | **60** | **336** | 38900 | **319** | 6340 | 529 | 4.1 | **3240** | 2.50 | 62 | 18 | 691 |
| | 10-20 cm | 6620 | 0.8 | 20.3 | 135 | 0.6 | 1.76 | 21500 | 21 | 47 | 249 | 32800 | **290** | 5610 | 439 | 4.0 | **2920** | 1.80 | 64 | 14 | 551 |
| 2292563 (Front yard) | 0-5 cm | 22500 | <0.4 | 10.6 | 152 | 1.2 | 1.58 | 22400 | 45 | 50 | 210 | 25700 | 173 | 10400 | 433 | 5.1 | **1620** | <0.3 | 62 | 50 | 359 |
| | 5-10 cm | 23800 | <0.4 | 12.5 | 157 | 1.2 | 1.60 | 18600 | 48 | **63** | 277 | 29100 | 183 | 8290 | 490 | 4.7 | **2320** | 0.50 | 54 | 50 | 357 |
| | 10-20 cm | 23000 | 0.8 | **31.7** | 207 | **1.3** | 2.60 | 22500 | 45 | **112** | **598** | 41000 | **263** | 8400 | 540 | 4.9 | **7590** | 5.30 | 72 | 42 | 662 |
| 2292564 (Back yard) | 0-5 cm | 23200 | 1.4 | 19.1 | 203 | **1.3** | 2.30 | 17700 | 38 | 43 | 282 | 30200 | **274** | 6800 | 413 | 4.2 | **2030** | 0.50 | 85 | 47 | 578 |
| | 5-10 cm | 25200 | 3.3 | **29.3** | 323 | **1.6** | 2.27 | 19900 | 42 | 50 | **495** | 34600 | **446** | 6530 | 346 | 4.3 | **3210** | 0.70 | 119 | 47 | 635 |
| | 10-20 cm | 25500 | 1.3 | **28.6** | 266 | **1.6** | 2.06 | 21600 | 40 | 41 | **359** | 30200 | **258** | 6560 | 297 | 3.9 | **2780** | 0.70 | 133 | 46 | 512 |
| 2292565 (Front yard) | 0-5 cm | 23900 | <0.4 | 12.7 | 190 | **1.3** | 1.80 | 22800 | 35 | 42 | **437** | 26000 | **244** | 9410 | 392 | 4.2 | **1900** | <0.3 | 86 | 47 | 336 |
| | 5-10 cm | 26500 | <0.4 | 15.0 | 202 | **1.5** | 1.76 | 24700 | 36 | 43 | 244 | 28300 | **226** | 10300 | 410 | 4.1 | **2140** | 0.40 | 99 | 50 | 306 |
| | 10-20 cm | 26100 | <0.4 | 14.5 | 202 | **1.5** | 1.53 | 24300 | 35 | 35 | 215 | 27200 | **203** | 8660 | 372 | 5.0 | **1930** | <0.3 | 115 | 48 | 273 |
| 2292566 (Back yard) | 0-5 cm | 18800 | 7.6 | 19.2 | 405 | **1.5** | 2.17 | 34500 | 40 | **52** | **306** | 28000 | **717** | 11200 | 495 | 4.4 | **2290** | 1.10 | 347 | 41 | 727 |
| | 5-10 cm | 22100 | **13.5** | **26.2** | 470 | **1.7** | 2.17 | 32300 | 45 | 50 | **393** | 33600 | **925** | 9970 | 465 | 4.4 | **2880** | 0.50 | 180 | 41 | 779 |
| | 10-20 cm | 22300 | **13.6** | **27.2** | 530 | **1.6** | 2.44 | 27100 | 68 | 46 | **372** | 32000 | **1100** | 7930 | 440 | 4.9 | **2720** | 0.50 | 173 | 42 | **853** |
| 2292567 (Front yard) | 0-5 cm | 21800 | 1.5 | 7.9 | 155 | 1.2 | 1.03 | 18600 | 33 | 31 | 153 | 24700 | **221** | 8390 | 415 | 3.5 | **1260** | <0.3 | 63 | 44 | 280 |
| | 0-5 cm | 20500 | <0.4 | 7.2 | 146 | 1.1 | 0.99 | 19200 | 29 | 28 | 137 | 24300 | 126 | 8280 | 377 | 3.6 | **1190** | <0.3 | 69 | 40 | 292 |
| | 0-5 cm | 22400 | <0.4 | 8.9 | 158 | 1.2 | 1.04 | 18400 | 32 | 30 | 149 | 26800 | 128 | 8380 | 412 | 3.7 | **1270** | <0.3 | 66 | 43 | 275 |
| | 5-10 cm | 23700 | <0.4 | 11.6 | 156 | **1.3** | 1.21 | 21400 | 33 | 40 | 199 | 29200 | 150 | 9600 | 450 | 3.7 | **1920** | <0.3 | 66 | 46 | 301 |
| | 5-10 cm | 20500 | <0.4 | 9.0 | 145 | 1.2 | 1.03 | 20800 | 32 | 31 | 167 | 31900 | 157 | 8390 | 408 | 3.7 | **1980** | <0.3 | 69 | 39 | 263 |
| | 5-10 cm | 21200 | <0.4 | 8.6 | 154 | 1.2 | 1.07 | 19900 | 32 | 34 | 175 | 32500 | 133 | 7870 | 391 | 3.5 | **2150** | <0.3 | 75 | 41 | 294 |
| | 10-20 cm | 24100 | <0.4 | 12.9 | 163 | **1.4** | 1.19 | 20700 | 33 | 40 | 229 | 44200 | 138 | 8910 | 404 | 3.9 | **3060** | <0.3 | 74 | 44 | 264 |
| | 10-20 cm | 22000 | <0.4 | 8.6 | 148 | 1.2 | 0.91 | 25100 | 30 | 30 | 152 | 32800 | 103 | 9970 | 427 | 3.7 | **2340** | <0.3 | 80 | 40 | 227 |
| | 10-20 cm | 27600 | <0.4 | 8.2 | 174 | **1.4** | 1.01 | 21700 | 35 | 33 | 173 | 36100 | 121 | 9180 | 445 | 3.6 | **1960** | <0.3 | 68 | 48 | 229 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292568 (Back yard) | 0-5 cm | 20300 | <0.4 | 9.8 | 217 | 1.2 | 1.47 | 21200 | 35 | 33 | 166 | 25700 | **237** | 7980 | 473 | 4.0 | **1340** | <0.3 | 107 | 41 | 514 |
| | 0-5 cm | 19000 | <0.4 | 8.4 | 203 | 1.2 | 1.41 | 19700 | 34 | 32 | 158 | 25200 | **298** | 7840 | 408 | 3.8 | **1360** | <0.3 | 96 | 40 | 498 |
| | 0-5 cm | 20400 | <0.4 | 8.3 | 208 | 1.2 | 1.47 | 20600 | 35 | 32 | 157 | 25400 | **230** | 8060 | 409 | 3.7 | **1320** | <0.3 | 97 | 41 | 503 |
| | 5-10 cm | 19500 | <0.4 | 9.2 | 195 | 1.2 | 1.44 | 22200 | 33 | 33 | 189 | 25100 | **229** | 8300 | 393 | 3.7 | **1440** | <0.3 | 102 | 40 | 489 |
| | 5-10 cm | 20400 | <0.4 | 9.3 | 219 | **1.4** | 1.43 | 20200 | 36 | 35 | 178 | 25700 | **252** | 8050 | 412 | 4.4 | **1410** | <0.3 | 114 | 45 | 551 |
| | 5-10 cm | 20900 | <0.4 | 8.5 | 199 | 1.1 | 1.48 | 21800 | 33 | 32 | 155 | 26800 | **242** | 8110 | 404 | 3.7 | **1420** | <0.3 | 95 | 39 | 463 |
| | 10-20 cm | 19800 | 0.6 | 8.6 | 191 | 1.2 | 1.31 | 18300 | 33 | 32 | 165 | 25300 | **223** | 7030 | 370 | 3.6 | **1440** | <0.3 | 89 | 40 | 440 |
| | 10-20 cm | 20600 | 0.9 | 9.7 | 217 | **1.3** | 1.50 | 18100 | 35 | 35 | 178 | 26200 | **280** | 7320 | 391 | 3.7 | **1540** | <0.3 | 104 | 41 | 511 |
| | 10-20 cm | 21900 | <0.4 | 10.4 | 216 | 1.2 | 1.49 | 20900 | 34 | 34 | 182 | 27700 | **272** | 7810 | 391 | 3.7 | **1730** | <0.3 | 96 | 39 | 480 |
| 2292569 (Front yard) | 0-5 cm | 30700 | <0.4 | 8.4 | 159 | **1.4** | 1.08 | 15500 | 36 | 32 | 141 | 30900 | 173 | 8710 | 437 | 3.5 | **1370** | <0.3 | 71 | 49 | 259 |
| | 5-10 cm | 32700 | <0.4 | 7.5 | 166 | **1.5** | 1.01 | 20600 | 37 | 32 | 137 | 33900 | 152 | 10000 | 449 | 3.6 | **1380** | <0.3 | 82 | 50 | 232 |
| | 10-20 cm | 29600 | <0.4 | 11.0 | 168 | **1.4** | 1.15 | 28800 | 34 | 34 | 172 | 33400 | 172 | 10700 | 461 | 3.6 | **1870** | <0.3 | 98 | 45 | 244 |
| 2292570 (Back yard) | 0-5 cm | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | 5-10 cm | 21100 | <0.4 | 7.8 | 136 | 1 | 0.91 | 27300 | 26 | 28 | 126 | 28600 | 159 | 9320 | 473 | 4.4 | **1200** | <0.3 | 70 | 36 | 245 |
| | 10-20 cm | 20300 | <0.4 | 9.9 | 145 | 1 | 0.98 | 33300 | 27 | 28 | 141 | 29000 | 168 | 9290 | 411 | 3.8 | **1490** | <0.3 | 79 | 34 | 245 |
| 2292571 (Front yard) | 0-5 cm | 19000 | 0.5 | 14.8 | 222 | 1 | 2.05 | 33400 | 31 | 50 | 242 | 29800 | **334** | 13800 | 449 | 4.1 | **2520** | 8.00 | 127 | 36 | 578 |
| | 5-10 cm | 18900 | 2.3 | 18.9 | 180 | 1 | 2.33 | 44300 | 29 | **56** | 286 | 33900 | **362** | 17500 | 473 | 4.4 | **3120** | 9.00 | 138 | 34 | 565 |
| | 10-20 cm | 25900 | <0.4 | 13.0 | 186 | **1.3** | 1.42 | 44500 | 31 | 31 | 176 | 32600 | 190 | 15300 | 585 | 4.1 | **1660** | <0.3 | 197 | 41 | 341 |
| 2292572 (Front yard) | 0-5 cm | 19900 | <0.4 | 12.6 | 223 | 1.2 | 1.90 | 24700 | 33 | 46 | 247 | 25900 | **342** | 10600 | 484 | 4.3 | **1910** | <0.3 | 70 | 41 | 542 |
| | 5-10 cm | 23600 | <0.4 | 19.6 | 274 | **1.4** | 2.10 | 26200 | 36 | **52** | 294 | 30700 | **341** | 10300 | 488 | 4.3 | **2880** | <0.3 | 125 | 45 | 522 |
| | 10-20 cm | 24200 | <0.4 | 11.5 | 206 | **1.4** | 1.21 | 35500 | 32 | 30 | 185 | 26700 | **222** | 12700 | 468 | 4.2 | **1450** | <0.3 | 87 | 44 | 334 |
| 2292573 (Back yard) | 0-5 cm | 18300 | 7.9 | 7.9 | 123 | 0.9 | 0.99 | 14100 | 27 | 21 | 124 | 20300 | 165 | 6670 | 476 | 3.5 | **563** | <0.3 | 62 | 36 | 246 |
| | 5-10 cm | 17200 | **34.5** | 14.1 | 176 | 1 | 1.80 | 24600 | 29 | 36 | **353** | 26000 | **554** | 9550 | 443 | 4.4 | **1400** | <0.3 | 89 | 36 | 471 |
| | 10-20 cm | 22600 | 91.1 | 27.1 | 326 | **1.4** | 2.59 | 24700 | 41 | 46 | **626** | 31900 | **782** | 9520 | 428 | 4.9 | **2370** | <0.3 | 124 | 43 | **822** |
| 2292574 (Front yard) | 0-5 cm | 26800 | <0.4 | 13.5 | 192 | **1.4** | 1.92 | 15300 | 37 | 49 | 221 | 31600 | **239** | 7950 | 821 | 4.1 | **2080** | <0.3 | 52 | 52 | 397 |
| | 5-10 cm | 30400 | <0.4 | 15.3 | 243 | **1.6** | 1.92 | 13600 | 41 | **51** | 248 | 36300 | **236** | 8160 | 731 | 3.9 | **2450** | <0.3 | 51 | 57 | 400 |
| | 10-20 cm | 25400 | <0.4 | 8.6 | 195 | **1.4** | 1.40 | 24400 | 31 | 26 | 198 | 28800 | **219** | 7540 | 588 | 4.0 | **1180** | <0.3 | 67 | 46 | 443 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292575 (Front yard) | 0-5 cm | 15600 | <0.4 | 15.3 | 187 | 0.9 | 1.41 | 22900 | 28 | **65** | 273 | 22200 | **505** | 8760 | 478 | 4.4 | **2770** | <0.3 | 53 | 36 | 565 |
| | 5-10 cm | 19400 | <0.4 | 23.8 | 206 | 1.1 | 1.72 | 18100 | 33 | **86** | **617** | 28000 | **428** | 8080 | 494 | 4.2 | **4550** | 1.20 | 49 | 41 | 607 |
| | 10-20 cm | 21800 | <0.4 | 15.7 | 183 | **1.3** | 1.09 | 24300 | 31 | 48 | 245 | 24500 | **302** | 8630 | 498 | 3.9 | **2860** | <0.3 | 62 | 41 | 362 |
| 2292576 (Back yard) | 0-5 cm | 14500 | <0.4 | 18.3 | 177 | 1 | 1.36 | 18000 | 24 | 40 | 220 | 20300 | **270** | 6080 | 382 | 3.8 | **1950** | 0.40 | 66 | 32 | 356 |
| | 5-10 cm | 13500 | <0.4 | 18.5 | 164 | 0.9 | 1.20 | 20700 | 22 | 34 | 192 | 20100 | **239** | 6230 | 355 | 3.8 | **1790** | <0.3 | 69 | 30 | 299 |
| | 10-20 cm | 13000 | <0.4 | 12.9 | 136 | 0.8 | 0.97 | 21600 | 18 | 20 | 116 | 15400 | 196 | 6590 | 293 | 3.7 | **883** | <0.3 | 74 | 28 | 216 |
| 2292577 (Front yard) | 0-5 cm | 20500 | <0.4 | 12.4 | 186 | 1.2 | 1.51 | 19800 | 30 | **54** | 278 | 25800 | **289** | 9100 | 445 | 4.2 | **2490** | <0.3 | 75 | 42 | 365 |
| | 0-5 cm | 18500 | <0.4 | 9.3 | 168 | 1.1 | 1.29 | 19200 | 27 | 48 | 233 | 23600 | **248** | 8840 | 397 | 4.3 | **2160** | <0.3 | 69 | 39 | 316 |
| | 0-5 cm | 20100 | | 12.1 | 194 | 1.2 | 1.50 | 20200 | 31 | **55** | 284 | 25600 | **283** | 9260 | 436 | 4.3 | **2530** | <0.3 | 72 | 43 | 377 |
| | 5-10 cm | 20600 | <0.4 | 20.4 | 285 | **1.4** | 2.04 | 29500 | 40 | **74** | **504** | 30300 | **491** | 11000 | 472 | 4.7 | **4870** | 0.60 | 97 | 40 | 588 |
| | 5-10 cm | 19700 | <0.4 | 17.6 | 241 | **1.4** | 1.77 | 28200 | 30 | **63** | **381** | 28000 | **392** | 10700 | 489 | 4.4 | **3780** | <0.3 | 107 | 39 | 481 |
| | 5-10 cm | 21000 | <0.4 | 15.8 | 253 | **1.4** | 1.59 | 27200 | 30 | **56** | **332** | 26700 | **383** | 10100 | 448 | 4.2 | **3020** | <0.3 | 97 | 41 | 441 |
| | 10-20 cm | 22600 | 0.6 | 19.0 | 283 | **1.4** | 1.81 | 30900 | 32 | **64** | **446** | 33800 | **456** | 10100 | 481 | 4.5 | **4770** | <0.3 | 102 | 41 | 465 |
| | 10-20 cm | 20800 | <0.4 | **28.0** | 323 | **1.5** | 2.26 | 30200 | 33 | **82** | **531** | 35200 | **485** | 9250 | 502 | 4.6 | **5990** | 1.20 | 114 | 38 | 684 |
| | 10-20 cm | 20600 | <0.4 | **27.4** | 327 | **1.3** | 2.51 | 39000 | 32 | **80** | **589** | 34300 | **570** | 10800 | 524 | 4.7 | **6060** | 1.10 | 117 | 37 | **901** |
| 2292578 (Back yard) | 0-5 cm | 20500 | 0.6 | 12.9 | 344 | 1.2 | 1.84 | 19100 | 35 | 43 | 282 | 25900 | **493** | 6840 | 390 | 4.1 | **1910** | <0.3 | 92 | 42 | 683 |
| | 0-5 cm | 17300 | 0.7 | 11.3 | 285 | 1 | 1.69 | 17000 | 39 | 39 | **437** | 23700 | **519** | 6150 | 351 | 4.0 | **1740** | <0.3 | 81 | 37 | 596 |
| | 0-5 cm | 15600 | 0.7 | 12.2 | 244 | 1 | 2.09 | 17400 | 29 | 40 | 238 | 23200 | **384** | 6410 | 351 | 4.1 | **1830** | 0.30 | 73 | 35 | 514 |
| | 5-10 cm | 20000 | 1.7 | 16.5 | 547 | 1.3 | 2.31 | 24800 | 41 | 48 | **441** | 32200 | **1430** | 7750 | 431 | 4.4 | **2660** | <0.3 | 113 | 38 | **960** |
| | 5-10 cm | 18300 | 1.7 | 19.0 | 624 | 1.1 | 2.43 | 25000 | 44 | 50 | **567** | 30600 | **661** | 7370 | 443 | 4.5 | **2690** | <0.3 | 116 | 35 | **1100** |
| | 5-10 cm | 16600 | 1.1 | 16.4 | 532 | 1.1 | 2.15 | 25000 | 39 | 46 | **351** | 27200 | **634** | 8060 | 399 | 4.4 | **2580** | <0.3 | 103 | 33 | **864** |
| | 10-20 cm | 15300 | 4.2 | 17.9 | 502 | 1.2 | 1.93 | 25300 | 35 | 36 | **350** | 26900 | **860** | 6150 | 317 | 4.3 | **2360** | <0.3 | 128 | 29 | **869** |
| | 10-20 cm | 14700 | 1.1 | 15.3 | 600 | 1 | 1.84 | 24500 | 33 | 35 | **327** | 25700 | **686** | 6240 | 345 | 4.1 | **2230** | <0.3 | 105 | 29 | **846** |
| | 10-20 cm | 12900 | 1.9 | 20.4 | 430 | 0.9 | 2.27 | 25600 | 37 | 40 | **513** | 25700 | **746** | 6440 | 335 | 4.3 | **2720** | 0.30 | 108 | 28 | **812** |
| 2292579 (Front yard) | 0-5 cm | 12000 | <0.4 | 1.2 | 50 | 0.6 | 0.32 | 6090 | 19 | 12 | 37 | 17300 | 37 | 4330 | 580 | 2.7 | 139 | <0.3 | 20 | 25 | 69 |
| | 5-10 cm | 12100 | <0.4 | 1.9 | 42 | 0.6 | 0.21 | 5420 | 15 | 10 | 25 | 18100 | 20 | 4070 | 655 | 2.4 | 60 | <0.3 | 18 | 24 | 47 |
| | 10-20 cm | 11300 | <0.4 | 2.1 | 41 | 0.6 | 0.20 | 11800 | 15 | 9 | 27 | 32200 | 20 | 5550 | 1140 | 3.3 | 64 | <0.3 | 24 | 24 | 59 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292580 (Back yard) | 0-5 cm | 33500 | <0.4 | 15.9 | 254 | 1.1 | 2.48 | 24900 | 37 | 47 | 250 | 45800 | **338** | 7720 | 386 | 4.8 | **3300** | <0.3 | 90 | 37 | 494 |
| | 5-10 cm | 37000 | <0.4 | 20.5 | 287 | 1.2 | 2.20 | 46700 | 39 | 47 | 261 | 49500 | **566** | 7940 | 397 | 4.3 | **3610** | <0.3 | 114 | 39 | 521 |
| | 10-20 cm | 33600 | 0.8 | 21.6 | 289 | 1.1 | 2.12 | 55000 | 39 | 39 | 241 | 45700 | **707** | 8080 | 385 | 4.3 | **3110** | <0.3 | 125 | 34 | 463 |
| 2292581 (Front yard) | 0-5 cm | 30900 | <0.4 | 21.4 | 130 | 0.8 | 1.32 | 11100 | 24 | 42 | 212 | 40400 | 149 | 5620 | 467 | 3.8 | **3220** | <0.3 | 39 | 33 | 282 |
| | 5-10 cm | 32600 | <0.4 | 21.0 | 128 | 0.9 | 1.39 | 11800 | 23 | 40 | 186 | 42900 | 136 | 5820 | 894 | 3.5 | **3260** | <0.3 | 42 | 33 | 256 |
| | 10-20 cm | 38900 | <0.4 | 19.2 | 145 | 1.1 | 1.21 | 45300 | 27 | 38 | 196 | 50200 | 129 | 9790 | 1170 | 4.0 | **3000** | <0.3 | 62 | 38 | 235 |
| 2292582 (Back yard) | 0-5 cm | 14500 | <0.4 | 13.9 | 90 | 0.6 | 1.09 | 5680 | 20 | 22 | 85 | 32800 | 83 | 2980 | 421 | 3.0 | **755** | <0.3 | 29 | 29 | 211 |
| | 5-10 cm | 14400 | <0.4 | 12.2 | 89 | 0.6 | 1.09 | 5660 | 20 | 21 | 84 | 33600 | 84 | 2970 | 434 | 3.1 | **722** | <0.3 | 29 | 29 | 212 |
| | 10-20 cm | 13900 | <0.4 | 18.9 | 157 | 0.8 | 1.44 | 10700 | 22 | 31 | 149 | 27000 | 151 | 4100 | 718 | 3.5 | **1480** | <0.3 | 54 | 29 | 427 |
| 2292583 (Front yard) | 0-5 cm | 22500 | <0.4 | 4.5 | 107 | 1 | 0.91 | 9070 | 26 | 33 | 109 | 23200 | 68 | 5260 | 371 | 4.0 | **864** | <0.3 | 40 | 43 | 256 |
| | 5-10 cm | 17200 | <0.4 | 4.9 | 98 | 0.9 | 0.78 | 7650 | 24 | 34 | 140 | 22100 | 66 | 4410 | 356 | 3.3 | **1140** | <0.3 | 42 | 39 | 197 |
| | 10-20 cm | 25200 | <0.4 | 7.0 | 130 | 1.1 | 0.88 | 16300 | 28 | 37 | 154 | 28900 | 65 | 8720 | 481 | 3.7 | **1600** | <0.3 | 54 | 46 | 218 |
| 2292584 (Front yard) | 0-5 cm | 21000 | <0.4 | 7.8 | 154 | 1 | 1.51 | 25000 | 32 | **86** | 287 | 25600 | 120 | 12300 | 500 | 4.1 | **3000** | <0.3 | 61 | 41 | 217 |
| | 5-10 cm | 23600 | <0.4 | 7.9 | 165 | 1.1 | 2.19 | 26600 | 31 | **88** | **306** | 27500 | 107 | 13500 | 528 | 4.1 | **2770** | <0.3 | 53 | 44 | 214 |
| | 10-20 cm | 28000 | <0.4 | 30.5 | 213 | **1.4** | 1.80 | 28800 | 41 | **151** | **653** | 54500 | 150 | 13700 | 670 | 4.9 | **10400** | 1.50 | 60 | 49 | 415 |
| 2292585 (Back yard) | 0-5 cm | 15700 | <0.4 | 5.7 | 111 | 0.8 | 1.00 | 22700 | 29 | 39 | 191 | 21000 | 100 | 8710 | 347 | 4.5 | **1820** | <0.3 | 81 | 30 | 214 |
| | 5-10 cm | 18500 | <0.4 | 7.8 | 128 | 1 | 1.11 | 27200 | 25 | 49 | 236 | 24000 | 113 | 11500 | 400 | 4.2 | **2100** | <0.3 | 88 | 36 | 250 |
| | 10-20 cm | 20900 | <0.4 | 12.8 | 142 | 1 | 1.14 | 35500 | 28 | **64** | **489** | 29600 | 152 | 17500 | 494 | 4.4 | **4030** | <0.3 | 88 | 39 | 283 |
| 2292587 (Front yard) | 0-5 cm | 38300 | <0.4 | 1.8 | 305 | **1.7** | 1.87 | 36000 | 54 | 47 | 153 | 35900 | **371** | 14700 | 661 | 4.3 | **1240** | <0.3 | 118 | 64 | 416 |
| | 5-10 cm | 40500 | <0.4 | 6.8 | 514 | **1.8** | 3.78 | 37900 | 53 | **109** | **809** | 40100 | **552** | 16300 | 681 | 4.9 | **3470** | <0.3 | 133 | 69 | **931** |
| | 10-20 cm | 41200 | <0.4 | 7.1 | 345 | **1.8** | 1.73 | 51800 | 49 | **82** | **415** | 41400 | **216** | 19800 | 646 | 4.7 | **2960** | <0.3 | 431 | 69 | 415 |
| 2292588 (Back yard) | 0-5 cm | 34000 | <0.4 | 1.4 | 193 | **1.5** | 0.57 | 33900 | 38 | 30 | 103 | 31700 | 98 | 16400 | 576 | 4.3 | **873** | <0.3 | 101 | 57 | 160 |
| | 5-10 cm | 37300 | <0.4 | 2.5 | 205 | **1.6** | 0.54 | 34400 | 39 | 29 | 91 | 34900 | 118 | 15800 | 746 | 4.1 | **675** | <0.3 | 114 | 61 | 195 |
| | 10-20 cm | 45800 | <0.4 | 0.3 | 278 | **2** | 0.75 | 40800 | 67 | 27 | 60 | 40200 | 103 | 17300 | 788 | 4.5 | **373** | <0.3 | 120 | 73 | 146 |
| 2292589 (Front yard) | 0-5 cm | 30100 | <0.4 | 3.0 | 201 | **1.3** | 0.61 | 52500 | 34 | 35 | 96 | 29600 | 104 | 21600 | 574 | 4.5 | **910** | <0.3 | 144 | 52 | 175 |
| | 5-10 cm | 36700 | <0.4 | 0.6 | 202 | **1.6** | 0.43 | 53600 | 39 | 20 | 54 | 33800 | 49 | 21000 | 585 | 4.1 | **201** | <0.3 | 126 | 60 | 156 |
| | 10-20 cm | 34200 | <0.4 | 1.3 | 228 | **1.5** | 0.65 | 37900 | 38 | 48 | 129 | 38600 | 97 | 18400 | 806 | 4.1 | **1540** | <0.3 | 102 | 57 | 161 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292590 (Back yard) | 0-5 cm | 29800 | <0.4 | 2.0 | 176 | **1.3** | 0.46 | 45500 | 32 | 21 | 69 | 29500 | 55 | 21900 | 516 | 4.4 | **357** | <0.3 | 94 | 50 | 117 |
| | 5-10 cm | 34400 | <0.4 | 1.6 | 192 | **1.5** | 0.75 | 35800 | 38 | 22 | 108 | 31600 | 61 | 19200 | 452 | 4.1 | **380** | <0.3 | 84 | 56 | 111 |
| | 10-20 cm | 31900 | <0.4 | 5.0 | 188 | **1.3** | 0.58 | 33000 | 37 | 32 | 134 | 29600 | 116 | 18600 | 487 | 4.1 | **1310** | <0.3 | 75 | 52 | 159 |
| 2292591 (Front yard) | 0-5 cm | 16600 | <0.4 | 17.8 | 220 | 1 | 2.25 | 27600 | 37 | **222** | **646** | 34300 | **237** | 13400 | 598 | 4.9 | **9760** | 3.90 | 63 | 41 | 747 |
| | 5-10 cm | 29000 | <0.4 | 16.1 | 272 | **1.4** | 1.76 | 35100 | 41 | **136** | **504** | 41100 | **203** | 15200 | 618 | 4.7 | **6640** | 0.30 | 83 | 55 | 580 |
| | 10-20 cm* | 19975 | 1.4 | **27.1** | 204 | 1 | 1.55 | 26300 | 35 | **144** | **658** | 47625 | **222** | 10825 | 559 | 2.2 | **11825** | 2.08 | 63 | 48 | 473 |
| 2292592 (Back yard) | 0-5 cm | 33900 | <0.4 | 11.5 | 353 | **1.6** | 1.28 | 24700 | 44 | **85** | **339** | 44100 | **250** | 13000 | 773 | 4.7 | **4740** | <0.3 | 95 | 60 | 431 |
| | 5-10 cm | 38400 | <0.4 | 13.3 | 319 | **1.9** | 1.24 | 14900 | 47 | **80** | **329** | 43000 | **249** | 10700 | 461 | 4.4 | **5350** | <0.3 | 98 | 67 | 353 |
| | 10-20 cm | 47300 | <0.4 | 8.3 | 294 | **2.1** | 0.58 | 17600 | 52 | 49 | 193 | 50800 | 94 | 14400 | 840 | 4.0 | **2610** | <0.3 | 85 | 75 | 194 |
| 2292593 (Front yard) | 0-5 cm | 26400 | <0.4 | 15.3 | 340 | **1.3** | 2.02 | 18800 | 41 | **144** | **452** | 42400 | **238** | 9330 | 641 | 4.4 | **6430** | 0.80 | 65 | 54 | 539 |
| | 0-5 cm | 26700 | <0.4 | 12.9 | 284 | **1.3** | 1.66 | 23100 | 40 | **159** | **428** | 42600 | **274** | 9990 | 710 | 4.3 | **5860** | 1.00 | 74 | 51 | 514 |
| | 0-5 cm | 29700 | <0.4 | 11 | 268 | 1 | 1.34 | 21000 | 41 | **129** | **325** | 40800 | **262** | 10200 | 636 | 4 | **4390** | <0.3 | 72 | 57 | 418 |
| | 5-10 cm | 26900 | <0.4 | 15.5 | 349 | **1.3** | 1.55 | 22600 | 41 | **87** | **393** | 40900 | **231** | 9960 | 603 | 4.8 | **5110** | <0.3 | 84 | 52 | 497 |
| | 5-10 cm | 24700 | <0.4 | 24.1 | 449 | 1.2 | 2.95 | 24800 | 50 | **146** | **722** | 55000 | **420** | 9700 | 716 | 5.3 | **9030** | 2.60 | 82 | 49 | **936** |
| | 5-10 cm | 30500 | <0.4 | 14.6 | 370 | **1.4** | 2.34 | 22800 | 47 | **82** | **398** | 42600 | **326** | 11200 | 600 | 4.3 | **4340** | <0.3 | 71 | 57 | 648 |
| | 10-20 cm* | 23800 | 4.5 | **46.2** | 517 | **1.4** | **35.33** | 23313 | 50 | **159** | **890** | 56050 | **771** | 8583 | 712 | 3.0 | **12350** | 4.78 | 105 | 51 | **945** |
| | 10-20 cm | 26400 | <0.4 | **27.2** | 512 | **1.4** | 3.31 | 22700 | 52 | **121** | **653** | 48600 | **553** | 9040 | 624 | 5.3 | **8530** | 2.20 | 102 | 51 | **960** |
| | 10-20 cm | 39600 | <0.4 | 5 | 290 | 2 | 1.17 | 29500 | 47 | 38 | 144 | 39500 | 170 | 13600 | 720 | 4 | **1420** | <0.3 | 87 | 66 | 300 |
| 2292594 (Back yard) | 0-5 cm | 15000 | <0.4 | 23.8 | 452 | 1 | 2.62 | 21500 | 42 | **172** | **640** | 38600 | **603** | 7530 | 542 | 4.8 | **8470** | 6.40 | 93 | 37 | **1020** |
| | 0-5 cm | 15800 | <0.4 | **26.0** | 440 | 1.2 | 2.56 | 21300 | 43 | **163** | **645** | 39700 | **614** | 6790 | 539 | 5.1 | **7940** | 5.00 | 121 | 38 | **1060** |
| | 0-5 cm* | 15025 | 1.6 | **30.5** | 323 | 1 | 1.54 | 20350 | 37 | **177** | **532** | 39575 | **427** | 6530 | 590 | 2.5 | **8473** | 5.13 | 98 | 39 | 769 |
| | 5-10 cm* | 15675 | 2.1 | **43.0** | 417 | 1 | 1.73 | 22350 | 40 | **144** | **776** | 47450 | **674** | 7795 | 545 | 2.7 | **10960** | 6.25 | 96 | 37 | **1230** |
| | 5-10 cm | 18000 | <0.4 | **35.6** | 464 | **1.3** | 3.33 | 21300 | 44 | **171** | **823** | 52100 | **750** | 6570 | 561 | 5.2 | **13400** | 5.80 | 127 | 37 | **1160** |
| | 5-10 cm* | 18325 | 1.0 | **36.0** | 375 | 1.1 | 1.91 | 19900 | 41 | **139** | **772** | 48800 | **582** | 7550 | 622 | 3.4 | **10650** | 5.61 | 93 | 39 | **981** |
| | 10-20 cm* | 14675 | 1.5 | **29.7** | 329 | 1 | 1.94 | 22925 | 39 | **86** | **526** | 45975 | **549** | 6853 | 498 | 4.1 | **6855** | 3.78 | 107 | 34 | **1075** |
| | 10-20 cm* | 17775 | 1.1 | **26.6** | 342 | 1 | 1.61 | 21975 | 36 | **86** | **629** | 40450 | **512** | 6600 | 466 | 3.3 | **7448** | 3.76 | 112 | 38 | **849** |
| | 10-20 cm* | 17950 | 0.9 | **32.9** | 348 | 1.1 | 1.60 | 22125 | 37 | **102** | **605** | 44075 | **546** | 7010 | 532 | 3.5 | **8540** | 4.00 | 115 | 37 | **866** |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292595 (Front yard) | 0-5 cm* | 13200 | 0.4 | 6.3 | 85 | 0.6 | 0.47 | 7518 | 18 | 33 | 103 | 17975 | 78 | 4195 | 417 | 2.1 | **1213** | 0.66 | 31 | 31 | 150 |
| | 5-10 cm | 14900 | <0.4 | 10.4 | 174 | 0.9 | 0.86 | 13700 | 25 | **54** | 233 | 23300 | 199 | 5710 | 435 | 3.8 | **2730** | <0.3 | 64 | 34 | 300 |
| | 10-20 cm | 12500 | <0.4 | 12.0 | 143 | 0.8 | 0.71 | 23000 | 25 | 50 | 262 | 21500 | 167 | 6890 | 353 | 3.9 | **3170** | 0.60 | 72 | 29 | 283 |
| 2292596 (Back yard) | 0-5 cm | 14600 | <0.4 | 2.9 | 93 | 0.8 | 0.24 | 26800 | 18 | **52** | 66 | 16300 | 37 | 10500 | 373 | 3.8 | **550** | <0.3 | 75 | 33 | 135 |
| | 5-10 cm | 15400 | <0.4 | 2.3 | 94 | 0.9 | 0.23 | 30200 | 18 | 37 | 61 | 16700 | 37 | 11300 | 367 | 3.7 | **547** | <0.3 | 84 | 34 | 104 |
| | 10-20 cm | 14100 | <0.4 | 4 | 94 | 1 | 0.24 | 34000 | 19 | **60** | 68 | 16100 | 39 | 12000 | 406 | 4 | **675** | <0.3 | 96 | 34 | 100 |
| 2292597 (Front yard) | 0-5 cm | 19000 | <0.4 | 13.5 | 235 | 1.2 | 1.67 | 19900 | 40 | **63** | **301** | 33100 | **409** | 6720 | 508 | 4.6 | **3460** | 0.60 | 95 | 37 | 539 |
| | 5-10 cm | 19800 | 1.0 | 16.9 | 245 | **1.4** | 1.78 | 21500 | 40 | **64** | **328** | 33900 | **368** | 6860 | 540 | 4.5 | **3590** | 0.70 | 106 | 38 | 530 |
| | 10-20 cm | 16800 | <0.4 | 24.2 | 256 | **1.6** | 2.14 | 22200 | 39 | **85** | **428** | 42000 | **363** | 6220 | 566 | 5.3 | **5940** | 2.43 | 143 | 35 | 587 |
| 2292598 (Back yard) | 0-5 cm | 12300 | 0.8 | 9.7 | 138 | 0.7 | 1.72 | 14300 | 45 | 46 | 180 | 21500 | **210** | 4920 | 303 | 3.9 | **2190** | 0.40 | 60 | 26 | 323 |
| | 5-10 cm | 12900 | 1.7 | 13.6 | 158 | 0.8 | 1.86 | 17700 | 44 | **51** | 207 | 20600 | **364** | 5330 | 326 | 4.1 | **2440** | 0.64 | 67 | 27 | 336 |
| | 10-20 cm | 12500 | 0.7 | 16.3 | 213 | 1.2 | 1.79 | 18800 | 36 | **56** | 257 | 22300 | **289** | 5160 | 335 | 4.4 | **3000** | 0.70 | 145 | 28 | 400 |
| 2292599 (Front yard) | 0-5 cm | 13800 | <0.4 | 8.1 | 87 | 0.6 | 0.99 | 11800 | 21 | 43 | 156 | 22500 | 111 | 5730 | 406 | 3.6 | **2140** | <0.3 | 34 | 28 | 245 |
| | 5-10 cm* | 13850 | 0.4 | 10.6 | 79 | 0.5 | 0.78 | 9158 | 20 | 40 | 151 | 20825 | 93 | 4440 | 367 | 2.3 | **1963** | 0.60 | 28 | 29 | 214 |
| | 10-20 cm | 14600 | <0.4 | 10.9 | 77 | 0.7 | 1.04 | 8890 | 23 | 48 | 212 | 25400 | 98 | 4340 | 403 | 3.5 | **2990** | 0.30 | 29 | 27 | 235 |
| 2292600 (Back yard) | 0-5 cm | 13300 | <0.4 | 7.8 | 75 | 0.5 | 0.96 | 6900 | 25 | 41 | 138 | 17600 | 118 | 3250 | 258 | 3.1 | **1750** | <0.3 | 33 | 27 | 268 |
| | 5-10 cm | 13600 | <0.4 | 3.8 | 48 | 0.5 | 0.56 | 3970 | 16 | 21 | 67 | 15000 | 58 | 2400 | 200 | 2.6 | **837** | 0.30 | 24 | 26 | 129 |
| | 10-20 cm | 14100 | 6.4 | 6.7 | 71 | 0.6 | 1.10 | 4930 | 20 | 36 | 135 | 20800 | 101 | 2770 | 273 | 3.0 | **1640** | <0.3 | 24 | 26 | 205 |
| 2292601 (Front yard) | 0-5 cm | 4580 | <0.4 | 1.3 | 22 | 0.2 | 0.18 | 18000 | 8 | 5 | 8 | 8820 | 8 | 5380 | 240 | 3.2 | 48 | <0.3 | 34 | 16 | 30 |
| | 5-10 cm | 4880 | <0.4 | 2.7 | 19 | 0.3 | 0.18 | 19400 | 9 | 5 | 6 | 10100 | 6 | 5480 | 236 | 3.3 | 38 | <0.3 | 37 | 19 | 23 |
| | 10-20 cm | 32100 | 0.7 | | 134 | 1.2 | 0.18 | 6520 | 40 | 16 | 8 | 27100 | 35 | 8050 | 220 | 3.3 | 38 | <0.3 | 73 | 63 | 74 |
| 2292602 (Back yard) | 0-5 cm | 5970 | <0.4 | 4.1 | 61 | 0.3 | 0.71 | 19100 | 13 | 30 | 99 | 12400 | 74 | 5960 | 286 | 3.6 | **1040** | <0.3 | 60 | 20 | 195 |
| | 5-10 cm | 12900 | 0.7 | 22.5 | 304 | 0.8 | 2.82 | 19100 | 31 | **85** | **486** | 37100 | **334** | 6430 | 465 | 4.5 | **6240** | 4.90 | 81 | 30 | **990** |
| | 10-20 cm | 18600 | 0.7 | **28.3** | 230 | 1.1 | 2.81 | 32000 | 33 | **80** | **2720** | 41000 | **355** | 8820 | 474 | 5.1 | **7410** | 3.78 | 113 | 36 | **1210** |
| 2292603 (Front yard) | 0-5 cm | 24700 | <0.4 | 12.2 | 191 | 1.2 | 1.53 | 16100 | 32 | **58** | 264 | 27700 | 146 | 7860 | 430 | 4.5 | **2860** | 0.69 | 72 | 45 | 310 |
| | 5-10 cm | 26600 | <0.4 | 11.2 | 185 | 1.3 | 1.41 | 13900 | 33 | 50 | 236 | 27300 | 115 | 7570 | 405 | 4.3 | **2560** | <0.3 | 68 | 47 | 260 |
| | 10-20 cm | 18000 | <0.4 | **30.3** | 221 | 1.1 | 2.23 | 15700 | 38 | **101** | **612** | 48500 | **206** | 6740 | 682 | 5.0 | **7920** | 3.90 | 69 | 34 | 546 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292604 (Back yard) | 0-5 cm | 5630 | <0.4 | 4.1 | 39 | 0.3 | 0.43 | 20000 | 11 | 13 | 39 | 11500 | 43 | 6580 | 249 | 3.7 | **419** | <0.3 | 54 | 21 | 82 |
| | 5-10 cm | 6580 | 0.4 | 9.5 | 95 | 0.5 | 0.96 | 17800 | 14 | 30 | 136 | 14800 | 163 | 5230 | 280 | 4.0 | **1500** | 0.56 | 81 | 20 | 232 |
| | 10-20 cm | 17400 | 6.8 | **41.2** | 533 | **1.8** | 4.31 | 19700 | 49 | **153** | **791** | 60200 | **1800** | 5700 | 722 | 6.2 | **10300** | 5.75 | 190 | 38 | **1350** |
| 2292605 (Front yard) | 0-5 cm | 16700 | <0.4 | 20.2 | 232 | 1 | 2.53 | 35500 | 35 | **90** | **491** | 37200 | **389** | 16200 | 622 | 5.7 | **5700** | 2.80 | 124 | 34 | 667 |
| | 0-5 cm | 18100 | <0.4 | 18.1 | 254 | 1.1 | 2.71 | 28400 | 35 | **81** | **444** | 35700 | **327** | 12800 | 599 | 5.4 | **4890** | 2.66 | 114 | 36 | 620 |
| | 0-5 cm | 15500 | <0.4 | 20.9 | 206 | 0.9 | 2.83 | 26300 | 34 | **88** | **502** | 37400 | **351** | 11900 | 593 | 5.2 | **5780** | 3.11 | 95 | 32 | 662 |
| | 5-10 cm | 21500 | <0.4 | **34.1** | 235 | 1.2 | 3.33 | 22700 | 44 | **138** | **739** | 57400 | **372** | 10200 | 799 | 6.7 | **9570** | 4.01 | 89 | 40 | 766 |
| | 5-10 cm | 21200 | <0.4 | **25.5** | 240 | **1.3** | 2.58 | 24600 | 37 | **113** | **610** | 48100 | **313** | 10700 | 718 | 5.3 | **7820** | 2.90 | 91 | 40 | 740 |
| | 5-10 cm | 19300 | <0.4 | **33.2** | 218 | 1.2 | 3.22 | 20800 | 40 | **146** | **799** | 58000 | **376** | 9520 | 818 | 5.4 | **9520** | 4.98 | 85 | 36 | **844** |
| | 10-20 cm | 18000 | <0.4 | **40.8** | 265 | 1.2 | 3.37 | 24900 | 38 | **134** | **888** | 59400 | **392** | 9040 | 836 | 6.0 | **10800** | 5.03 | 90 | 32 | 794 |
| | 10-20 cm | 18000 | <0.4 | **31.9** | 216 | 1.2 | 2.74 | 24300 | 35 | **113** | **716** | 48000 | **306** | 9540 | 719 | 5.3 | **8160** | 3.47 | 89 | 36 | 758 |
| | 10-20 cm | 18100 | <0.4 | **28.0** | 212 | 1.1 | 3.04 | 22700 | 34 | **107** | **654** | 48200 | **333** | 9670 | 725 | 5.3 | **8230** | 3.81 | 94 | 35 | 686 |
| 2292606 (Back yard) | 0-5 cm | 19000 | <0.4 | 16.7 | 250 | 1.1 | 1.92 | 25700 | 34 | **88** | **391** | 36500 | **284** | 10200 | 1280 | 5.8 | **4230** | 2.20 | 134 | 36 | 519 |
| | 0-5 cm | 20000 | 0.5 | 18.8 | 194 | 1.2 | 1.84 | 13700 | 35 | **96** | **392** | 35400 | 196 | 6800 | 680 | 4.7 | **4710** | 2.76 | 91 | 43 | 433 |
| | 0-5 cm | 21400 | 0.8 | 22.3 | 241 | **1.3** | 3.01 | 14700 | 39 | **101** | **447** | 36800 | **269** | 6230 | 702 | 5.0 | **4910** | 3.42 | 114 | 43 | 537 |
| | 5-10 cm | 22300 | 3.1 | 22.0 | 307 | 1.2 | 2.54 | 13500 | 46 | **96** | **465** | 45200 | **408** | 6480 | 671 | 5.1 | **5700** | 2.79 | 82 | 42 | 666 |
| | 5-10 cm | 26500 | 0.5 | 24.5 | 224 | **1.4** | 1.97 | 14300 | 43 | **100** | **504** | 48900 | **220** | 7660 | 750 | 4.8 | **6450** | 1.98 | 78 | 45 | 548 |
| | 5-10 cm | 23100 | 1.2 | 24.8 | 253 | **1.4** | 2.33 | 13700 | 43 | **113** | **554** | 50200 | **241** | 6500 | 964 | 5.1 | **7110** | 2.51 | 103 | 42 | 604 |
| | 10-20 cm | 22400 | 1.9 | **29.0** | 252 | **1.3** | 2.38 | 16400 | 46 | **113** | **559** | 53900 | **320** | 7430 | 766 | 5.4 | **7830** | 3.72 | 87 | 41 | 689 |
| | 10-20 cm | 27700 | 0.6 | **33.4** | 267 | **1.5** | 2.17 | 19600 | 49 | **99** | **541** | 53700 | **252** | 9160 | 847 | 5.1 | **7690** | 3.00 | 99 | 47 | 583 |
| | 10-20 cm | 23300 | 0.4 | **32.1** | 271 | **1.5** | 2.24 | 17500 | 46 | **113** | **567** | 55500 | **309** | 7560 | 836 | 5.6 | **8190** | 3.76 | 120 | 42 | 599 |
| 2292608 (Back yard) | 0-5 cm | 13500 | <0.4 | 19.0 | 131 | 0.8 | 1.88 | 15100 | 27 | **90** | **339** | 35100 | 185 | 5410 | 628 | 4.6 | **4140** | 2.66 | 60 | 27 | 450 |
| | 5-10 cm | 12600 | 0.6 | 24.7 | 119 | 0.7 | 1.93 | 16000 | 30 | **90** | **378** | 42900 | 88 | 5180 | 715 | 4.5 | **4780** | 2.11 | 56 | 25 | 442 |
| | 10-20 cm | 12900 | 0.7 | 20.5 | 102 | 0.7 | 1.73 | 16800 | 25 | **73** | **338** | 35500 | 157 | 5370 | 591 | 4.6 | **4560** | 1.34 | 56 | 26 | 364 |
| 2292609 (Back yard) | 0-5 cm | 22900 | <0.4 | 2.9 | 125 | 1 | 0.54 | 7170 | 30 | 23 | 68 | 22900 | 58 | 5840 | 415 | 3.4 | **670** | <0.3 | 66 | 41 | 140 |
| | 5-10 cm | 28800 | <0.4 | 1.1 | 143 | 1.2 | 0.43 | 5680 | 33 | 20 | 44 | 26600 | 47 | 6690 | 433 | 3.1 | **392** | <0.3 | 37 | 50 | 106 |
| | 10-20 cm | 36200 | <0.4 | 1.9 | 177 | **1.5** | 0.47 | 6640 | 42 | 23 | 47 | 33700 | 54 | 8330 | 500 | 3.7 | **390** | <0.3 | 52 | 61 | 124 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292610 (Front yard) | 0-5 cm | 14800 | <0.4 | 6.0 | 100 | 0.5 | 0.51 | 6390 | 17 | 23 | 69 | 16300 | 73 | 3380 | 241 | 6.3 | **685** | <0.3 | 25 | 25 | 152 |
| | 5-10 cm | 14700 | <0.4 | 5.5 | 94 | 0.4 | 0.44 | 5250 | 17 | 22 | 62 | 14500 | 61 | 3050 | 237 | 6.2 | **708** | <0.3 | 21 | 25 | 123 |
| | 10-20 cm | 16600 | 0.4 | 11.0 | 135 | 0.6 | 0.76 | 8280 | 22 | 36 | 156 | 21800 | 122 | 4630 | 390 | 8.2 | **1490** | <0.3 | 30 | 30 | 217 |
| 2292611 (Back yard) | 0-5 cm | 16400 | 0.5 | 9.9 | 146 | 0.6 | 0.90 | 8910 | 22 | 30 | 110 | 22700 | 123 | 4920 | 482 | 8.3 | **808** | <0.3 | 33 | 30 | 232 |
| | 5-10 cm | 17700 | <0.4 | 11.0 | 161 | 0.7 | 0.86 | 10100 | 24 | 32 | 109 | 23400 | 129 | 5500 | 491 | 8.8 | **820** | <0.3 | 36 | 32 | 246 |
| | 10-20 cm | 18600 | 1.2 | 13.2 | 180 | 0.8 | 1.29 | 14900 | 30 | 40 | 153 | 27700 | 190 | 6590 | 487 | 10.3 | **1190** | <0.3 | 51 | 35 | 341 |
| 2292612 (Front yard) | 0-5 cm | 17100 | 0.7 | 12.2 | 141 | 0.8 | 0.75 | 23400 | 26 | 47 | 144 | 27200 | 137 | 12100 | 547 | 10.6 | **1380** | <0.3 | 57 | 35 | 233 |
| | 5-10 cm | 19300 | 0.9 | 12.5 | 150 | 1 | 0.79 | 28600 | 29 | 48 | 150 | 29700 | 137 | 15800 | 626 | 11.8 | **1370** | <0.3 | 66 | 37 | 238 |
| | 10-20 cm | 19300 | 0.8 | 12.0 | 132 | 0.9 | 0.73 | 29100 | 29 | 47 | 144 | 31500 | 101 | 15200 | 678 | 11.7 | **1470** | <0.3 | 60 | 36 | 203 |
| 2292613 (Back yard) | 0-5 cm | 20700 | 0.9 | 10.5 | 158 | 1 | 0.98 | 21100 | 30 | 40 | 123 | 27400 | 118 | 11400 | 556 | 11.0 | **1030** | <0.3 | 54 | 39 | 222 |
| | 5-10 cm | 21700 | 0.9 | 9.8 | 159 | 1 | 0.95 | 28600 | 29 | 40 | 115 | 28200 | 112 | 15200 | 593 | 11.6 | **936** | <0.3 | 61 | 40 | 210 |
| | 10-20 cm | 23500 | 0.5 | 9.6 | 150 | 1 | 0.78 | 33200 | 31 | 39 | 100 | 29800 | 79 | 16300 | 630 | 12.1 | **836** | <0.3 | 66 | 42 | 166 |
| 2292614 (Side yard) | 0-5 cm | 17500 | 1.4 | 17.4 | 131 | 0.9 | 0.87 | 19900 | 27 | **56** | 210 | 30600 | 116 | 8560 | 512 | 10.6 | **2270** | 1.00 | 59 | 34 | 218 |
| | 5-10 cm | 21700 | 1.1 | 17.8 | 151 | 1 | 0.77 | 24500 | 33 | **57** | 202 | 32600 | 108 | 10100 | 548 | 11.8 | **2080** | <0.3 | 64 | 41 | 211 |
| | 10-20 cm | 21300 | 1.5 | 17.8 | 154 | 1 | 0.96 | 20600 | 30 | **57** | 210 | 34000 | 121 | 8720 | 599 | 11.6 | **2190** | 0.80 | 67 | 39 | 216 |
| 2292615 (Front yard) | 0-5 cm | 13600 | <0.4 | 7.6 | 95 | 0.6 | 3.13 | 16900 | 25 | 25 | 58 | 18800 | 105 | 7920 | 488 | 8.1 | **430** | <0.3 | 51 | 31 | 140 |
| | 0-5 cm | 13500 | <0.4 | 5.8 | 95 | 0.5 | 0.94 | 19600 | 21 | 24 | 56 | 17200 | 83 | 8780 | 434 | 7.9 | **418** | <0.3 | 50 | 30 | 124 |
| | 0-5 cm | 16500 | 1.1 | 6.9 | 125 | 0.7 | 1.33 | 18300 | 26 | 29 | 67 | 21500 | 97 | 9370 | 501 | 9.2 | **503** | <0.3 | 62 | 35 | 159 |
| | 5-10 cm | 14000 | <0.4 | 5.6 | 98 | 0.6 | 0.78 | 20200 | 21 | 25 | 49 | 19300 | 73 | 8550 | 491 | 8.4 | **330** | <0.3 | 55 | 32 | 119 |
| | 5-10 cm | 10700 | <0.4 | 3.6 | 63 | 0.4 | 0.43 | 18900 | 17 | 19 | 37 | 14500 | 55 | 9010 | 316 | 7.0 | **277** | <0.3 | 45 | 28 | 85 |
| | 5-20 cm | 13500 | <0.4 | 6.3 | 98 | 0.6 | 0.84 | 17500 | 21 | 25 | 60 | 19200 | 83 | 8460 | 471 | 8.2 | **412** | <0.3 | 69 | 31 | 133 |
| | 10-20 cm | 19900 | 0.5 | 7.6 | 139 | 0.9 | 0.75 | 22700 | 28 | 31 | 60 | 25100 | 75 | 9160 | 621 | 10.3 | **406** | <0.3 | 79 | 40 | 136 |
| | 10-20 cm | 17500 | <0.4 | 7.1 | 123 | 0.8 | 0.61 | 22500 | 26 | 28 | 60 | 22200 | 93 | 10400 | 474 | 9.7 | **402** | <0.3 | 78 | 38 | 147 |
| | 10-20 cm | 22900 | 0.5 | 7.1 | 147 | 1 | 0.83 | 15400 | 31 | 33 | 60 | 27200 | 77 | 9950 | 679 | 10.8 | **412** | <0.3 | 64 | 45 | 133 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292616 (Back yard) | 0-5 cm | 11000 | <0.4 | 6.5 | 76 | 0.4 | 1.26 | 13700 | 18 | 22 | 59 | 15800 | 103 | 6280 | 467 | 7.0 | **352** | <0.3 | 36 | 26 | 134 |
| | 0-5 cm | 13300 | <0.4 | 7.7 | 96 | 0.5 | 0.77 | 12000 | 20 | 25 | 68 | 17900 | 119 | 6300 | 521 | 7.7 | **396** | <0.3 | 40 | 29 | 164 |
| | 0-5 cm | 12600 | 0.4 | 7.6 | 79 | 0.4 | 0.81 | 13400 | 18 | 24 | 67 | 16500 | 111 | 6530 | 481 | 7.2 | **418** | <0.3 | 37 | 27 | 162 |
| | 5-10 cm | 9880 | <0.4 | 6.9 | 78 | 0.4 | 0.88 | 20500 | 15 | 23 | 72 | 15500 | 116 | 7740 | 361 | 7.1 | **446** | <0.3 | 51 | 25 | 161 |
| | 5-10 cm | 11600 | <0.4 | 6.3 | 86 | 0.4 | 0.91 | 15200 | 16 | 22 | 61 | 16400 | 145 | 7250 | 460 | 7.2 | **351** | <0.3 | 41 | 26 | 175 |
| | 5-10 cm | 11100 | 0.4 | 6.6 | 74 | 0.4 | 1.26 | 15600 | 15 | 24 | 68 | 15600 | 123 | 7180 | 394 | 7.1 | **426** | <0.3 | 40 | 25 | 282 |
| | 10-20 cm | 11300 | 0.6 | 7.6 | 98 | 0.4 | 0.87 | 22700 | 18 | 27 | 88 | 18500 | 140 | 9150 | 379 | 8.0 | **582** | <0.3 | 66 | 29 | 192 |
| | 10-20 cm | 12600 | <0.4 | 6.9 | 113 | 0.5 | 1.03 | 19800 | 18 | 26 | 76 | 17400 | 131 | 8690 | 423 | 7.9 | **479** | <0.3 | 71 | 27 | 246 |
| | 10-20 cm | 8070 | <0.4 | 5.2 | 56 | 0.3 | 1.39 | 16800 | 13 | 21 | 54 | 13600 | 95 | 7390 | 271 | 6.5 | **364** | <0.3 | 38 | 23 | 408 |
| 2292617 (Front yard) | 0-5 cm | 16900 | 1.4 | 16.4 | 177 | 0.9 | 1.43 | 24200 | 31 | **57** | 238 | 29700 | **316** | 10400 | 615 | 11.7 | **1920** | 0.60 | 84 | 34 | 361 |
| | 5-10 cm | 17900 | <0.4 | 15.3 | 158 | 1.1 | 1.72 | 19200 | 36 | 50 | 259 | 33700 | **251** | 8440 | 646 | 4.7 | **2630** | 1.40 | 70 | 36 | 401 |
| | 10-20 cm | 19800 | <0.4 | 15.7 | 160 | 1.2 | 1.56 | 19200 | 32 | 46 | 251 | 32900 | 196 | 8930 | 638 | 4.6 | **2430** | 0.90 | 65 | 37 | 316 |
| 2292618 (Front yard) | 0-5 cm | 13900 | <0.4 | 2.4 | 83 | 0.7 | 0.66 | 26700 | 24 | 13 | 43 | 19100 | 64 | 10100 | 487 | 4.4 | 107 | <0.3 | 60 | 28 | 131 |
| | 5-10 cm | 15700 | <0.4 | 2.3 | 94 | 0.8 | 0.56 | 29500 | 32 | 16 | 42 | 21500 | 67 | 10000 | 567 | 4.7 | 101 | <0.3 | 67 | 31 | 117 |
| | 10-20 cm | na | na | na | na | na | na | na | na | na | na | na | na | na | na | na | na | na | na | na | na |
| 2292619 (Back yard) | 0-5 cm | 13500 | <0.4 | 2.7 | 79 | 0.7 | 0.72 | 27200 | 23 | 14 | 47 | 18700 | 69 | 10300 | 519 | 4.3 | 196 | <0.3 | 56 | 27 | 132 |
| | 5-10 cm | 13900 | <0.4 | 4.1 | 82 | 0.7 | 0.69 | 30800 | 21 | 12 | 37 | 19000 | 51 | 11100 | 514 | 4.3 | 97 | <0.3 | 61 | 29 | 112 |
| 2292620 (Front yard) | 0-5 cm | 10100 | <0.4 | 5.8 | 149 | 0.6 | 1.16 | 18400 | 25 | 22 | 81 | 21300 | **254** | 7560 | 582 | 4.2 | **986** | <0.3 | 42 | 25 | 267 |
| | 5-10 cm | 10900 | 0.4 | 4.8 | 167 | 0.6 | 1.07 | 14400 | 26 | 18 | 64 | 21200 | **324** | 6590 | 605 | 3.8 | **591** | <0.3 | 33 | 25 | 233 |
| | 10-20 cm | 10900 | 3.6 | 15.9 | 389 | 0.9 | 2.36 | 24000 | 43 | **64** | 290 | 43100 | **769** | 9070 | 680 | 5.3 | **5940** | 0.80 | 82 | 24 | 591 |
| 2292621 (Back yard) | 0-5 cm | 15900 | <0.4 | 4.1 | 87 | 0.8 | 0.47 | 20000 | 22 | 14 | 45 | 18000 | 82 | 10100 | 362 | 3.9 | **298** | <0.3 | 35 | 32 | 135 |
| | 5-10 cm | 17700 | <0.4 | 2.4 | 96 | 0.8 | 0.44 | 24400 | 23 | 13 | 38 | 19000 | 77 | 11200 | 377 | 4.1 | **228** | <0.3 | 36 | 34 | 127 |
| | 10-20 cm | 20500 | <0.4 | 2.3 | 98 | 1 | 0.39 | 17900 | 25 | 12 | 31 | 21900 | 40 | 8760 | 440 | 3.7 | **184** | <0.3 | 31 | 39 | 100 |
| 2292622 (Front yard) | 0-5 cm | 18400 | 0.7 | 3.8 | 111 | 1 | 0.65 | 19500 | 26 | 19 | 77 | 21900 | 115 | 10600 | 443 | 4.3 | **450** | <0.3 | 42 | 34 | 173 |
| | 5-10 cm | 19400 | <0.4 | 4.3 | 117 | 1 | 0.58 | 21100 | 28 | 18 | 61 | 22200 | 92 | 11600 | 544 | 4.1 | **367** | <0.3 | 40 | 36 | 145 |
| 2292623 (Back yard) | 0-5 cm | 15400 | <0.4 | 3.4 | 90 | 0.8 | 0.58 | 15400 | 22 | 16 | 53 | 18300 | 97 | 7800 | 349 | 3.8 | **341** | <0.3 | 33 | 31 | 163 |
| | 5-10 cm | 15400 | <0.4 | 4.4 | 96 | 0.8 | 0.66 | 16700 | 22 | 16 | 55 | 18400 | 122 | 7960 | 348 | 3.8 | **381** | | 35 | 32 | 186 |
| | 10-20 cm | 9150 | <0.4 | 2.5 | 55 | 0.5 | 0.39 | 22900 | 14 | 10 | 31 | 12700 | 96 | 7340 | 266 | 3.8 | **199** | <0.3 | 35 | 22 | 119 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292624 (Front yard) | 0-5 cm | 23000 | 6.1 | 22.0 | 208 | **1.3** | 2.13 | 27600 | 37 | **70** | **383** | 41400 | **332** | 9140 | 687 | 5.2 | **4100** | 2.40 | 85 | 40 | 427 |
| | 5-10 cm | 25200 | 5.8 | 22.9 | 220 | **1.4** | 2.01 | 30000 | 34 | **61** | **347** | 41900 | **286** | 9260 | 680 | 4.8 | **4010** | 2.30 | 89 | 42 | 377 |
| | 10-20 cm | 21900 | 6.0 | 19.9 | 213 | **1.3** | 1.86 | 32800 | 28 | **63** | **334** | 37800 | **279** | 8220 | 651 | 4.9 | **3800** | 2.10 | 102 | 37 | 359 |
| 2292625 (Back yard) | 0-5 cm | 29100 | 5.1 | 18.6 | 234 | **1.3** | 2.18 | 26400 | 38 | 41 | 190 | 34700 | **289** | 12300 | 626 | 4.8 | **1750** | <0.3 | 133 | 49 | 330 |
| | 5-10 cm | 31000 | 5.6 | 17.1 | 230 | **1.3** | 1.35 | 29600 | 39 | 38 | 221 | 35900 | **302** | 13600 | 687 | 4.7 | **1680** | <0.3 | 146 | 51 | 287 |
| | 10-20 cm | 32700 | 6.2 | 12.0 | 249 | **1.5** | 1.48 | 29500 | 39 | 44 | 197 | 37000 | **212** | 13200 | 617 | 5.0 | **1730** | <0.3 | 160 | 53 | 299 |
| 2292626 (Side yard) | 0-5 cm | 21600 | 5.2 | 12.9 | 174 | 1 | 1.16 | 17700 | 29 | 37 | 162 | 26400 | 197 | 8470 | 403 | 4.1 | **1610** | 0.40 | 77 | 38 | 222 |
| | 5-10 cm | 27300 | 5.5 | 14.9 | 213 | 1.2 | 1.36 | 21400 | 35 | 47 | 203 | 33500 | **264** | 10200 | 488 | 4.7 | **2090** | 0.40 | 95 | 46 | 273 |
| | 10-20 cm | 24700 | 5.5 | 20.6 | 218 | 1.2 | 1.60 | 24200 | 34 | 46 | 218 | 31100 | **290** | 10000 | 440 | 4.5 | **2190** | 0.90 | 126 | 43 | 299 |
| 2292627 (Front yard) | 0-5 cm | 21600 | 5.6 | 15.9 | 189 | 1 | 1.44 | 20500 | 33 | **76** | 296 | 32300 | **263** | 9080 | 470 | 4.8 | **2850** | 1.10 | 82 | 39 | 332 |
| | 5-10 cm | 21900 | 5.5 | 20.5 | 172 | 1.1 | 1.51 | 19400 | 30 | **62** | 275 | 31200 | 179 | 7280 | 416 | 4.4 | **2890** | 2.40 | 84 | 39 | 262 |
| | 10-20 cm | 30400 | 5.9 | 18.9 | 205 | **1.4** | 1.60 | 21000 | 36 | **64** | **302** | 40100 | 160 | 8760 | 540 | 4.7 | **3480** | 1.60 | 92 | 52 | 278 |
| 2292628 (Back yard) | 0-5 cm | 22100 | 4.7 | 13.2 | 178 | 1.1 | 1.30 | 25500 | 35 | **64** | 237 | 31200 | 198 | 11200 | 554 | 4.8 | **2400** | 0.90 | 108 | 42 | 325 |
| | 5-10 cm | 31600 | 5.0 | 7.9 | 192 | **1.3** | 0.83 | 15100 | 39 | 36 | 144 | 31600 | 124 | 9300 | 561 | 4.4 | **1460** | <0.3 | 73 | 53 | 238 |
| | 10-20 cm | 22700 | 6.5 | 10.1 | 149 | 1 | 0.85 | 25800 | 36 | 35 | 180 | 29900 | 146 | 10200 | 954 | 5.1 | **1870** | 0.60 | 73 | 38 | 342 |
| 2292629 (Front yard) | 0-5 cm | 17500 | 4.6 | **28.2** | 200 | 1.1 | 2.47 | 19000 | 35 | **193** | **676** | 43900 | **291** | 7370 | 766 | 5.1 | **7870** | 8.60 | 81 | 38 | 592 |
| | 0-5 cm | 13300 | 5.4 | **36.1** | 204 | 0.9 | 2.91 | 16200 | 43 | **209** | **780** | 65800 | **373** | 5960 | 865 | 5.9 | **10600** | 10.00 | 64 | 32 | 794 |
| | 0-5 cm | 12000 | 6.2 | **30.8** | 195 | 0.9 | 2.73 | 16500 | 36 | **181** | **674** | 53300 | **407** | 5810 | 758 | 5.2 | **9460** | 9.90 | 65 | 30 | 733 |
| | 5-10 cm | 16500 | 5.7 | **42.6** | 197 | 1 | 3.03 | 14100 | 37 | **150** | **734** | 55800 | **346** | 5610 | 760 | 4.9 | **9860** | 8.50 | 57 | 31 | 721 |
| | 5-10 cm | 17600 | 6.5 | **57.8** | 254 | 1.2 | 4.30 | 17300 | 53 | **262** | **1100** | 83300 | **459** | 6350 | 1050 | 6.4 | **15600** | **19.40** | 71 | 31 | **1160** |
| | 5-10 cm | 15700 | 6.1 | **44.6** | 253 | 1.1 | 3.57 | 15700 | 47 | **218** | **949** | 71000 | **421** | 5770 | 876 | 5.9 | **13100** | **14.20** | 66 | 32 | **934** |
| | 10-20 cm | 19300 | 5.5 | **29.4** | 172 | 1.1 | 2.03 | 15700 | 29 | **75** | **450** | 38300 | **211** | 5670 | 572 | 4.2 | **5720** | 4.30 | 60 | 40 | 399 |
| | 10-20 cm | 13800 | 4.5 | 11.0 | 101 | 0.8 | 0.85 | 11200 | 22 | 34 | 182 | 29700 | 92 | 4930 | 353 | 3.4 | **2600** | 0.90 | 37 | 41 | 188 |
| | 10-20 cm | 10700 | 4.3 | 18.2 | 109 | 0.7 | 1.52 | 12200 | 22 | **62** | **304** | 33900 | 185 | 4990 | 441 | 4.0 | **4330** | 3.80 | 39 | 31 | 348 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292630 (Back yard) | 0-5 cm | 14600 | 4.5 | 10.1 | 141 | 0.8 | 1.33 | 20900 | 23 | 36 | 163 | 24800 | 156 | 6850 | 457 | 4.2 | **1650** | 0.80 | 63 | 29 | 349 |
| | 0-5 cm | 10300 | 4.5 | 8.2 | 121 | 0.6 | 1.16 | 22400 | 21 | 32 | 129 | 21500 | 188 | [illegible]510 | [illegible]34 | 4.0 | **1410** | 0.80 | 59 | 24 | 322 |
| | 0-5 cm | 13300 | 6.0 | 10.9 | 164 | 0.8 | 1.66 | 22300 | 25 | 39 | 172 | 23200 | **244** | 7870 | 401 | 4.3 | **1580** | 1.00 | 75 | 27 | 447 |
| | 5-10 cm | 15900 | 6.0 | 17.1 | 264 | 1 | 1.92 | 24900 | 28 | 44 | 257 | 31900 | **351** | 7540 | 443 | 4.6 | **2750** | 2.70 | 87 | 30 | 615 |
| | 5-10 cm | 15700 | 7.5 | 22.4 | 295 | 1.1 | 2.78 | 27700 | 33 | **61** | **402** | 38500 | **448** | 8190 | 533 | 4.8 | **3780** | 2.40 | 117 | 31 | 751 |
| | 5-10 cm | 13600 | 6.1 | 14.8 | 182 | 0.9 | 1.89 | 26200 | 27 | **51** | 246 | 32000 | **298** | 8220 | 435 | 4.0 | **2720** | 1.90 | 79 | 30 | 492 |
| | 10-20 cm | 19600 | 6.1 | 23.1 | 219 | 1.2 | 2.11 | 31200 | 31 | 44 | 274 | 35300 | **252** | 10100 | 526 | 4.7 | **2800** | 1.80 | 101 | 37 | 492 |
| | 10-20 cm | 17400 | 8.3 | 21.9 | 281 | 1.2 | 2.12 | 29400 | 32 | **55** | **337** | 39800 | **612** | 8150 | 545 | 4.8 | **3830** | 1.80 | 126 | 32 | 625 |
| | 10-20 cm | 19300 | 6.6 | 23.7 | 383 | **1.6** | 2.35 | 31800 | 34 | 48 | **358** | 37700 | **498** | 8320 | 548 | 4.8 | **3200** | 1.50 | 165 | 37 | 692 |
| 2292631 (Front yard) | 0-5 cm | 20800 | 4.0 | 5.4 | 88 | 0.7 | 0.52 | 4960 | 23 | 22 | 70 | 21100 | 63 | 3970 | 311 | 3.0 | **914** | <0.3 | 24 | 35 | 123 |
| | 5-10 cm | 20800 | 3.5 | 5.7 | 89 | 0.7 | 0.56 | 5840 | 23 | 22 | 75 | 22000 | 63 | 4280 | 329 | 3.3 | **927** | <0.3 | 23 | 36 | 125 |
| | 10-20 cm | 23100 | 4.4 | 13.0 | 137 | 1 | 0.96 | 12000 | 30 | 36 | 164 | 28800 | 113 | 6120 | 423 | 4.0 | **2120** | 1.10 | 38 | 40 | 197 |
| 2292632 (Back yard) | 0-5 cm | 37700 | 4.6 | 2.9 | 171 | 1.3 | 0.64 | 8990 | 39 | 21 | 67 | 27200 | 84 | 6940 | 306 | 3.6 | **646** | <0.3 | 51 | 55 | 152 |
| | 5-10 cm | 27800 | <0.4 | 8.7 | 174 | 1.2 | 0.98 | 11900 | 37 | 32 | 118 | 28900 | 125 | 7080 | 379 | 3.8 | **1140** | <0.3 | 55 | 51 | 228 |
| | 10-20 cm | 20000 | 5.3 | 17.7 | 164 | 0.9 | 1.47 | 15900 | 30 | 45 | 200 | 32100 | 200 | 6840 | 487 | 4.1 | **2290** | 0.60 | 59 | 37 | 295 |
| 2292633 (Front yard) | 0-5 cm | 26300 | 4.4 | 8.5 | 187 | 1.2 | 1.12 | 14600 | 33 | 36 | 160 | 28600 | 190 | 6580 | 451 | 4.1 | **1710** | <0.3 | 59 | 45 | 272 |
| | 5-10 cm | 28200 | 5.0 | 10.4 | 225 | **1.3** | 1.26 | 15900 | 35 | 41 | 190 | 32300 | **226** | 7470 | 529 | 4.2 | **2170** | <0.3 | 63 | 47 | 307 |
| | 10-20 cm | 28800 | 5.7 | 11.7 | 220 | **1.3** | 1.23 | 31300 | 34 | 39 | 212 | 35400 | **202** | 10500 | 587 | 4.7 | **2450** | <0.3 | 85 | 47 | 305 |
| 2292634 (Back yard) | 0-5 cm | 28000 | 4.6 | 8.3 | 182 | 1.2 | 1.24 | 12100 | 35 | 40 | 170 | 30900 | **276** | 6490 | 558 | 4.0 | **1740** | <0.3 | 45 | 48 | 304 |
| | 5-10 cm | 27600 | 5.3 | 6.2 | 165 | 1.2 | 0.95 | 10400 | 32 | 33 | 139 | 28500 | 150 | 6570 | 539 | 3.7 | **1450** | <0.3 | 38 | 46 | 224 |
| | 10-20 cm | 30000 | 5.7 | 9.5 | 208 | **1.4** | 1.09 | 23100 | 41 | 40 | 208 | 34400 | 190 | 10500 | 5620 | 5.1 | **2040** | <0.3 | 60 | 53 | 288 |
| 2292635 (Front yard) | 0-5 cm | 30000 | 5.5 | 8.0 | 180 | **1.3** | 1.14 | 14000 | 35 | 41 | 172 | 34200 | 132 | 7780 | 525 | 4.1 | **1990** | <0.3 | 53 | 50 | 240 |
| | 5-10 cm | 30800 | 5.1 | 8.9 | 187 | **1.3** | 1.06 | 13500 | 35 | 38 | 172 | 34300 | 134 | 7910 | 548 | 4.2 | **2030** | <0.3 | 52 | 51 | 221 |
| | 10-20 cm | 31200 | 5.6 | 11.1 | 212 | **1.4** | 1.12 | 22600 | 39 | 44 | 225 | 38900 | 160 | 9880 | 597 | 4.8 | **2790** | <0.3 | 65 | 51 | 260 |
| 2292636 (Front yard) | 0-5 cm | 19000 | 5.2 | 13.8 | 151 | 0.8 | 1.17 | 23800 | 27 | 45 | 225 | 31400 | 198 | 10800 | 490 | 4.6 | **3030** | 0.80 | 58 | 34 | 321 |
| | 5-10 cm | 17800 | 5.2 | 15.2 | 143 | 0.8 | 1.15 | 27300 | 26 | 46 | 229 | 32600 | 192 | 11600 | 540 | 4.6 | **3140** | 1.10 | 61 | 32 | 302 |
| | 10-20 cm | 17700 | 5 | 17 | 151 | 1 | 1.32 | 35600 | 27 | **51** | 259 | 35000 | 181 | 14100 | 604 | 5 | **3590** | 1 | 68 | 32 | 321 |
| 2292637 (Front yard) | 0-5 cm | 21600 | 5.1 | 14.5 | 188 | 1 | 1.64 | 16700 | 35 | **63** | 267 | 39100 | **248** | 8270 | 607 | 4.5 | **3830** | 1.30 | 56 | 38 | 418 |
| | 5-10 cm | 20400 | 6.6 | **27.1** | 203 | 1 | 2.16 | 16300 | 37 | **86** | **386** | 49500 | **302** | 7780 | 688 | 4.7 | **6420** | 3.6 | 49 | 34 | 521 |
| | 10-20 cm | 20300 | 6.1 | 19.4 | 186 | 1 | 1.58 | 14900 | 31 | **54** | 254 | 35900 | **223** | 7010 | 562 | 4.3 | **3650** | 1.40 | 47 | 37 | 341 |

## Table 6-3: Results of Chemical Analysis (µg/g) of 2000 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site / Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292638 (Back yard) | 0-5 cm | 17500 | 5.4 | 12.3 | 175 | 0.9 | 1.14 | 19800 | 31 | 47 | 205 | 35700 | **263** | 8210 | 521 | 4.5 | **2850** | 0.80 | 66 | 36 | 352 |
| | 5-10 cm | 24100 | 8 | 15 | 232 | 1 | 1.22 | 21900 | 36 | 50 | 287 | 39500 | **428** | 9310 | 598 | 5 | **2810** | 0 | 81 | 44 | 374 |
| | 10-20 cm | 24300 | 6.8 | 13.0 | 272 | 1.2 | 1.14 | 21500 | 36 | 43 | 207 | 37600 | **406** | 8510 | 491 | 4.4 | **2630** | 0.40 | 89 | 43 | 404 |
| 2292640 (Back yard) | 0-5 cm | 15300 | <0.4 | 1.7 | 65 | 0.6 | 0.72 | 4990 | 17 | 17 | 51 | 14700 | 53 | 3120 | 226 | 2.7 | **420** | <0.3 | 19 | 30 | 113 |
| | 5-10 cm | 15700 | <0.4 | 3.0 | 63 | 0.6 | 0.55 | 4380 | 16 | 17 | 47 | 14600 | 48 | 3050 | 224 | 2.6 | **429** | <0.3 | 18 | 30 | 99 |
| | 10-20 cm | 17800 | <0.4 | 5.2 | 89 | 0.8 | 0.69 | 7890 | 22 | 25 | 85 | 17900 | 79 | 4710 | 341 | 3.3 | **779** | <0.3 | 28 | 35 | 139 |
| <T | | 1000 | 1 | 1 | 5 | 2.5 | 1 | 500 | 5 | 2.5 | 5 | 1000 | 10 | 250 | 25 | 2.5 | 2.5 | 1 | 5 | 5 | 25 |
| ≤W | | 200 | 0.2 | 0.2 | 1 | 0.5 | 0.2 | 100 | 1 | 0.5 | 1 | 200 | 2 | 50 | 5 | 0.5 | 0.5 | 0.2 | 1 | 1 | 5 |

<T = a measurable trace amount; interpret with caution

≤W = no measurable response; less than reported value

## Table 6-4: Results of Chemical Analysis (μg/g) of 2001 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt,
Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium,
V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site/Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292702<br>(vacant lot) | 0-5 cm | 19000 | 0.5 | 13 | 170 | 1 | 0.3 | 33000 | 40 | 25 | 120 | 28000 | 180 | 13000 | 530 | 1.2 | **990** | 1.3 | 100 | 40 | 200 |
| | 0-5 cm | 20000 | 1.5 | 14 | 300 | 1 | 1 | 32000 | 36 | 23 | 120 | 28000 | **1600** | 13000 | 550 | 1.3 | **740** | 1.2 | 100 | 40 | 690 |
| | 5-10 cm | 21000 | 0.6 | 12 | 170 | 1.1 | 0.3 | 36000 | 32 | 26 | 120 | 29000 | 110 | 13000 | 560 | 0.9 | **1000** | 1.6 | 120 | 42 | 160 |
| | 5-10 cm | 21000 | 0.7 | 12 | 170 | 1.1 | 0.4 | 35000 | 29 | 24 | 97 | 28000 | 130 | 12000 | 540 | 0.6 | **880** | 1.4 | 100 | 42 | 170 |
| | 10-20 cm | 22000 | 0.5 | 13 | 160 | 1.1 | 0.1 | 32000 | 42 | 27 | 100 | 30000 | 76 | 11000 | 510 | 0.6 | **1100** | 1.8 | 110 | 43 | 140 |
| | 10-20 cm | 22000 | 0.5 | 11 | 160 | 1.1 | 0.3 | 35000 | 29 | 22 | 83 | 29000 | 70 | 12000 | 510 | 0.25 | **820** | 1.5 | 100 | 44 | 120 |
| 2292703<br>(front yard) | 0-5 cm | 13000 | 0.3 | 4.1 | 80 | 0.6 | 0.5 | 11000 | 18 | 8.7 | 23 | 14000 | 24 | 6000 | 300 | 0.25 | 46 | 0.3 | 50 | 29 | 67 |
| | 0-5 cm | 12000 | 0.1 | 4 | 77 | 0.6 | 0.3 | 12000 | 17 | 7.4 | 23 | 14000 | 26 | 6100 | 290 | 0.25 | 49 | 0.4 | 50 | 28 | 67 |
| | 5-10 cm | 14000 | 0.1 | 5.2 | 93 | 0.6 | 0.3 | 43000 | 19 | 8.4 | 21 | 18000 | 18 | 17000 | 430 | 0.25 | 31 | 0.1 | 100 | 32 | 62 |
| | 5-10 cm | 14000 | 0.1 | 4.4 | 90 | 0.6 | 0.4 | 28000 | 20 | 8.1 | 19 | 18000 | 22 | 12000 | 400 | 0.8 | 31 | 0.1 | 77 | 32 | 60 |
| | 10-20 cm | 18000 | 0.1 | 6.3 | 120 | 0.8 | 0.4 | 40000 | 23 | 11 | 21 | 24000 | 20 | 17000 | 560 | 0.25 | 27 | 0.1 | 130 | 40 | 66 |
| | 10-20 cm | 16000 | 0.1 | 6 | 110 | 0.8 | 0.1 | 46000 | 21 | 9.7 | 20 | 22000 | 17 | 18000 | 470 | 0.25 | 27 | 0.1 | 130 | 36 | 61 |
| 2292704<br>(front yard) | 0-5 cm | 12000 | 0.1 | 3.4 | 69 | 0.25 | 0.1 | 8300 | 16 | 6.4 | 21 | 13000 | 21 | 4800 | 270 | 0.25 | 46 | 0.3 | 52 | 27 | 65 |
| | 0-5 cm | 11000 | 0.1 | 3.2 | 70 | 0.25 | 0.4 | 10000 | 16 | 7 | 24 | 13000 | 21 | 5300 | 280 | 0.25 | 53 | 0.3 | 58 | 26 | 74 |
| | 5-10 cm | 12000 | 0.1 | 3.7 | 79 | 0.25 | 0.3 | 28000 | 16 | 6.7 | 23 | 15000 | 21 | 12000 | 330 | 0.25 | 37 | 0.1 | 100 | 29 | 60 |
| | 5-10 cm | 12000 | 0.1 | 3.6 | 74 | 0.25 | 0.5 | 25000 | 16 | 7.2 | 18 | 14000 | 21 | 10000 | 320 | 0.25 | 35 | 0.3 | 92 | 27 | 58 |
| | 10-20 cm | 11000 | 0.1 | 4.3 | 93 | 0.25 | 0.1 | 64000 | 16 | 7.9 | 20 | 16000 | 17 | 24000 | 440 | 0.25 | 25 | 0.1 | 180 | 28 | 63 |
| | 10-20 cm | 11000 | 0.1 | 4.1 | 92 | 0.25 | 0.1 | 67000 | 16 | 7.7 | 19 | 16000 | 11 | 25000 | 450 | 0.25 | 19 | 0.1 | 170 | 27 | 60 |
| 2292705<br>(front yard) | 0-5 cm | 12000 | 0.1 | 3.7 | 74 | 0.25 | 0.3 | 11000 | 17 | 7.8 | 26 | 14000 | 27 | 5400 | 280 | 0.6 | 50 | 0.3 | 45 | 27 | 74 |
| | 0-5 cm | 12000 | 0.3 | 3.5 | 72 | 0.25 | 0.6 | 13000 | 17 | 7.6 | 27 | 14000 | 31 | 5900 | 280 | 0.25 | 46 | 0.3 | 51 | 28 | 76 |
| | 5-10 cm | 12000 | 0.1 | 3.8 | 73 | 0.25 | 0.1 | 14000 | 16 | 7.3 | 19 | 14000 | 24 | 6600 | 280 | 0.25 | 35 | 0.3 | 60 | 26 | 57 |
| | 5-10 cm | 13000 | 0.3 | 3.7 | 75 | 0.25 | 0.6 | 18000 | 17 | 7.3 | 18 | 14000 | 24 | 8300 | 300 | 0.25 | 34 | 0.3 | 67 | 28 | 56 |
| | 10-20 cm | 11000 | 0.1 | 4.6 | 90 | 0.25 | 0.1 | 59000 | 16 | 7.9 | 20 | 17000 | 85 | 22000 | 440 | 0.25 | 21 | 0.1 | 140 | 28 | 60 |
| | 10-20 cm | 12000 | 0.3 | 5.1 | 92 | 0.6 | 0.1 | 60000 | 17 | 7.9 | 19 | 17000 | 20 | 22000 | 440 | 0.25 | 22 | 0.1 | 160 | 29 | 60 |
| 2292706<br>(front yard) | 0-5 cm | 15000 | 1 | 10 | 140 | 0.8 | 1.2 | 20000 | 57 | 47 | 230 | 24000 | 150 | 9800 | 470 | 3.4 | **1400** | 1.8 | 54 | 40 | 440 |
| | 0-5 cm | 14000 | 1.1 | 11 | 150 | 0.8 | 1.4 | 22000 | 37 | 42 | 220 | 23000 | 170 | 10000 | 460 | 3.3 | **1300** | 1.7 | 53 | 36 | 360 |
| | 5-10 cm | 15000 | 1.3 | 12 | 140 | 0.9 | 1.4 | 22000 | 53 | 45 | **320** | 25000 | 130 | 10000 | 460 | 2.7 | **1700** | 1.8 | 52 | 38 | 320 |
| | 5-10 cm | 16000 | 1 | 11 | 170 | 0.9 | 1.3 | 23000 | 33 | 42 | 250 | 27000 | 130 | 9900 | 500 | 2.2 | **1600** | 1.7 | 62 | 38 | 320 |
| | 10-20 cm | 18000 | 1 | 15 | 210 | 1.1 | 0.9 | 26000 | 31 | 37 | 230 | 26000 | 120 | 12000 | 450 | 1.8 | **1600** | 2 | 67 | 41 | 300 |
| | 10-20 cm | 15000 | 2.9 | 17 | 200 | 0.9 | 0.8 | 30000 | 25 | 37 | **390** | 26000 | 130 | 10000 | 440 | 0.25 | **2100** | 2.1 | 66 | 34 | 330 |
| 2292707<br>(back yard) | 0-5 cm | 9900 | 1.7 | 9.4 | 100 | 0.6 | 1.1 | 21000 | 22 | 31 | 160 | 20000 | 130 | 8900 | 360 | 1.1 | **1300** | 1.3 | 52 | 31 | 310 |
| | 0-5 cm | 9500 | 0.9 | 6.7 | 82 | 0.25 | 0.9 | 18000 | 19 | 19 | 93 | 16000 | 93 | 7100 | 310 | 1.1 | **710** | 1 | 42 | 26 | 250 |
| | 5-10 cm | 12000 | 1.6 | 12 | 120 | 0.7 | 1.2 | 24000 | 29 | 35 | 180 | 22000 | 140 | 9500 | 410 | 0.7 | **1400** | 1.5 | 66 | 33 | 320 |
| | 5-10 cm | 11000 | 4.4 | 12 | 130 | 0.7 | 1.1 | 26000 | 22 | 30 | 170 | 20000 | 140 | 9300 | 380 | 0.25 | **1200** | 1.6 | 61 | 30 | 300 |
| | 10-20 cm | 11000 | 2.3 | 18 | 190 | 0.8 | 1 | 28000 | 27 | 49 | **400** | 24000 | 180 | 9600 | 410 | 0.9 | **2700** | 2.7 | 100 | 32 | 400 |
| | 10-20 cm | 11000 | 2.6 | 18 | 160 | 0.7 | 1.1 | 25000 | 25 | **52** | **340** | 24000 | 180 | 8800 | 390 | 1.6 | **2600** | 2.7 | 75 | 30 | 420 |

## Table 6-4: Results of Chemical Analysis (µg/g) of 2001 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site/Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292708<br>(front yard) | 0-5 cm | 9300 | 1.2 | 17 | 140 | 0.6 | 0.5 | 20000 | 22 | 36 | 180 | 25000 | **220** | 6400 | 480 | 0.8 | **1900** | 2.6 | 80 | 25 | 360 |
| | 0-5 cm | 8900 | 1.7 | 13 | 130 | 0.25 | 0.6 | 19000 | 21 | 35 | 170 | 26000 | 190 | 6000 | 470 | 1 | **1800** | 2.3 | 73 | 25 | 330 |
| | 5-10 cm | 9100 | 1.4 | 19 | 140 | 0.6 | 0.3 | 19000 | 21 | 36 | 180 | 26000 | **200** | 5600 | 460 | 1.2 | **1900** | 2.6 | 72 | 25 | 340 |
| | 5-10 cm | 9400 | 1.6 | 14 | 150 | 0.6 | 0.6 | 19000 | 21 | 38 | 190 | 27000 | **210** | 5800 | 500 | 0.7 | **2000** | 2.5 | 79 | 26 | 360 |
| | 10-20 cm | 8100 | 1.4 | 19 | 140 | 0.25 | 0.4 | 20000 | 18 | 33 | 170 | 25000 | 190 | 5800 | 420 | 0.6 | **1900** | 2.4 | 68 | 23 | 330 |
| | 10-20 cm | 10000 | 1.5 | 15 | 180 | 0.6 | 0.6 | 22000 | 23 | 46 | 230 | 31000 | **240** | 6400 | 540 | 0.25 | **2600** | 2.3 | 84 | 27 | 420 |
| 2292709<br>(front yard) | 0-5 cm | 10000 | 1.1 | 14 | 100 | 0.6 | 0.4 | 24000 | 50 | 26 | 140 | 17000 | 170 | 8800 | 320 | 0.8 | **1400** | 2 | 61 | 26 | 270 |
| | 0-5 cm | 9800 | 1 | 14 | 94 | 0.25 | 0.6 | 24000 | 60 | 23 | 130 | 16000 | 150 | 9000 | 320 | 0.7 | **1200** | 1.8 | 57 | 24 | 250 |
| | 5-10 cm | 11000 | 1.2 | 16 | 100 | 0.6 | 0.6 | 23000 | 51 | 28 | 140 | 18000 | 170 | 8100 | 340 | 0.25 | **1600** | 1.9 | 51 | 28 | 260 |
| | 5-10 cm | 11000 | 1 | 16 | 100 | 0.6 | 0.4 | 24000 | 56 | 29 | 170 | 18000 | 180 | 8600 | 330 | 0.25 | **1600** | 2 | 54 | 28 | 270 |
| | 10-20 cm | 12000 | 0.7 | 11 | 110 | 0.6 | 0.8 | 19000 | 35 | 22 | 100 | 20000 | 150 | 6900 | 390 | 0.6 | **940** | 1.4 | 61 | 30 | 200 |
| | 10-20 cm | 10000 | 0.7 | 13 | 95 | 0.6 | 0.6 | 20000 | 27 | 21 | 110 | 18000 | 140 | 7500 | 370 | 0.6 | **920** | 2 | 55 | 26 | 180 |
| 2292710<br>(back yard) | 0-5 cm | 12000 | 0.8 | 13 | 110 | 0.6 | 0.6 | 26000 | 46 | 20 | 100 | 17000 | 120 | 9400 | 300 | 0.6 | **980** | 1.4 | 63 | 27 | 220 |
| | 0-5 cm | 12000 | 0.8 | 13 | 110 | 0.6 | 0.5 | 27000 | 42 | 20 | 100 | 17000 | 130 | 10000 | 310 | 0.7 | **980** | 1.4 | 65 | 29 | 230 |
| | 5-10 cm | 14000 | 1.1 | 14 | 120 | 0.7 | 0.3 | 32000 | 58 | 22 | 120 | 20000 | 180 | 13000 | 350 | 0.25 | **1200** | 1.5 | 68 | 32 | 230 |
| | 5-10 cm | 14000 | 0.7 | 16 | 120 | 0.7 | 0.3 | 32000 | 49 | 21 | 110 | 19000 | 130 | 13000 | 340 | 1 | **960** | 1.7 | 72 | 33 | 210 |
| | 10-20 cm | 18000 | 0.5 | 10 | 130 | 0.8 | 0.4 | 29000 | 30 | 14 | 47 | 23000 | 74 | 12000 | 380 | 0.25 | **330** | 0.8 | 69 | 38 | 110 |
| | 10-20 cm | 15000 | 0.4 | 9.8 | 100 | 0.7 | 0.1 | 36000 | 28 | 12 | 51 | 18000 | 71 | 16000 | 340 | 0.25 | **360** | 0.9 | 91 | 31 | 120 |
| 2292711<br>(side yard) | 0-5 cm | 19000 | 1.1 | 17 | 140 | 1 | 0.1 | 14000 | 27 | **77** | **320** | 21000 | 99 | 6900 | 410 | 0.25 | **3100** | 3.3 | 58 | 42 | 200 |
| | 0-5 cm | 21000 | 1.1 | 19 | 150 | 1.1 | 1 | 14000 | 31 | **83** | **360** | 23000 | 110 | 7000 | 510 | 0.25 | **3600** | 3.4 | 63 | 43 | 220 |
| | 5-10 cm | 26000 | 1 | 19 | 180 | **1.3** | 0.1 | 16000 | 33 | **62** | **300** | 24000 | 78 | 8900 | 380 | 0.25 | **3100** | 2.8 | 69 | 53 | 190 |
| | 5-10 cm | 23000 | 1.1 | 22 | 160 | **1.3** | 0.7 | 14000 | 31 | **80** | **390** | 24000 | 140 | 7200 | 390 | 0.25 | **4200** | 4.2 | 71 | 47 | 200 |
| | 10-20 cm | 21000 | 1.1 | 15 | 180 | 1.2 | 0.7 | 30000 | 41 | **63** | 250 | 27000 | 110 | 12000 | 600 | 2.9 | **2600** | 2.2 | 90 | 44 | 210 |
| | 10-20 cm | 24000 | 1.4 | 23 | 190 | **1.3** | 0.6 | 26000 | 46 | **82** | **410** | 32000 | 150 | 12000 | 580 | 0.25 | **4600** | 3.3 | 96 | 50 | 260 |
| 2292712<br>(side yard) | 0-5 cm | 17000 | 3.2 | 15 | 140 | 0.9 | 0.4 | 14000 | 29 | 50 | 210 | 30000 | 140 | 7600 | 440 | 0.8 | **2500** | 2.6 | 60 | 40 | 270 |
| | 0-5 cm | 17000 | 1.4 | 18 | 170 | 0.9 | 0.6 | 16000 | 41 | **62** | 270 | 34000 | 200 | 7400 | 500 | 1.1 | **3000** | 3.5 | 62 | 40 | 410 |
| | 5-10 cm | 21000 | 1.6 | 22 | 180 | 1.2 | 0.5 | 15000 | 35 | **64** | 300 | 41000 | 180 | 7900 | 580 | 0.6 | **3600** | 3.6 | 67 | 48 | 380 |
| | 5-10 cm | 20000 | 1.3 | 21 | 180 | 1.1 | 0.7 | 14000 | 36 | **60** | 280 | 38000 | 180 | 7700 | 620 | 0.7 | **3400** | 3.2 | 58 | 45 | 560 |
| | 10-20 cm | 21000 | 1.3 | 20 | 170 | 1.1 | 0.6 | 13000 | 33 | 42 | 210 | 36000 | 120 | 7500 | 570 | 0.7 | **2400** | 3 | 55 | 44 | 240 |
| | 10-20 cm | 22000 | 1.3 | 19 | 230 | 1.1 | 0.6 | 15000 | 38 | 44 | **330** | 35000 | 160 | 7800 | 520 | 0.7 | **2300** | 2.6 | 59 | 46 | 290 |
| 2292712<br>(front yard) | 0-5 cm | 7200 | 1.8 | 21 | 100 | 0.7 | 0.6 | 28000 | 24 | **120** | **420** | 52000 | **280** | 7500 | 820 | 1.5 | **4200** | 3.2 | 46 | 27 | 460 |
| | 0-5 cm | 6400 | 1.7 | 21 | 100 | 0.7 | 0.8 | 30000 | 21 | **100** | **330** | 37000 | **340** | 7500 | 710 | 0.9 | **3300** | 3.2 | 46 | 25 | 420 |
| | 5-10 cm | 6300 | 2.9 | **51** | 110 | 0.6 | 0.1 | 22000 | 35 | **180** | **680** | 110000 | **260** | 5800 | 890 | 2.2 | **8600** | 5.3 | 39 | 28 | 720 |
| | 5-10 cm | 6700 | 1.6 | **28** | 93 | 0.6 | 0.3 | 25000 | 24 | **98** | **570** | 67000 | **260** | 6600 | 780 | 1.8 | **5800** | 2.9 | 43 | 29 | 570 |
| | 10-20 cm | 3700 | 1 | 21 | 35 | 0.25 | 0.1 | 28000 | 9 | 24 | 200 | 22000 | 83 | 7400 | 340 | 0.25 | **1800** | 1.8 | 40 | 23 | 180 |
| | 10-20 cm | 3500 | 0.4 | 8.3 | 30 | 0.25 | 0.1 | 29000 | 10 | 15 | 120 | 17000 | 58 | 7200 | 260 | 0.25 | **1100** | 0.8 | 39 | 23 | 100 |

## Table 6-4: Results of Chemical Analysis (μg/g) of 2001 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site/Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292713<br>(side yard) | 0-5 cm | 2600 | 0.8 | 17 | 29 | 0.25 | 0.1 | 40000 | 10 | 16 | 74 | 13000 | 41 | 8800 | 250 | 0.8 | **650** | 1.5 | 50 | 10 | 130 |
| | 0-5 cm | 2900 | 0.5 | 10 | 31 | 0.25 | 0.4 | 41000 | 10 | 18 | 81 | 14000 | 60 | 8800 | 270 | 0.25 | **720** | 1.1 | 51 | 12 | 140 |
| | 5-10 cm | 2800 | 1.1 | 21 | 26 | 0.25 | 0.1 | 42000 | 9 | 20 | 97 | 18000 | 54 | 8600 | 280 | 0.6 | **890** | 5.5 | 51 | 14 | 150 |
| | 5-10 cm | 3500 | 0.8 | 16 | 40 | 0.25 | 0.1 | 45000 | 13 | 34 | 160 | 28000 | 86 | 8200 | 380 | 0.6 | **1600** | 1.8 | 53 | 16 | 220 |
| | 10-20 cm | 2800 | 0.6 | 13 | 27 | 0.25 | 0.1 | 39000 | 9 | 20 | 92 | 19000 | 46 | 8100 | 290 | 0.6 | **890** | 1.2 | 47 | 18 | 130 |
| | 10-20 cm | 3600 | 1.6 | 19 | 44 | 0.25 | 0.3 | 40000 | 13 | 37 | 200 | 29000 | 96 | 7700 | 400 | 0.9 | **1900** | 1.9 | 48 | 19 | 240 |
| 2292714<br>(back yard) | 0-5 cm | 3200 | 1.2 | 22 | 47 | 0.25 | 0.6 | 36000 | 12 | 34 | 130 | 26000 | 69 | 8200 | 400 | 1.2 | **1200** | 2.9 | 54 | 15 | 240 |
| | 0-5 cm | 2900 | 1.4 | 18 | 60 | 0.25 | 0.3 | 36000 | 12 | 26 | 100 | 22000 | 160 | 8400 | 340 | 0.25 | **930** | 1.8 | 50 | 15 | 230 |
| | 5-10 cm | 2800 | 0.9 | 21 | 46 | 0.25 | 0.4 | 36000 | 12 | 33 | 130 | 28000 | 66 | 8200 | 370 | 0.6 | **1200** | 2.4 | 49 | 16 | 220 |
| | 5-10 cm | 2500 | 0.8 | 14 | 37 | 0.25 | 0.3 | 35000 | 9 | 25 | 100 | 24000 | 77 | 8000 | 310 | 0.6 | **1000** | 1.4 | 47 | 17 | 160 |
| | 10-20 cm | 2200 | 0.7 | 16 | 24 | 0.25 | 0.1 | 34000 | 7 | 16 | 65 | 16000 | 27 | 7600 | 270 | 0.25 | **590** | 1.4 | 44 | 14 | 130 |
| | 10-20 cm | 2300 | 0.6 | 12 | 19 | 0.25 | 0.1 | 33000 | 7 | 15 | 63 | 16000 | 23 | 7800 | 260 | 0.25 | **580** | 1.2 | 43 | 14 | 110 |
| 2292714<br>(back yard) | 0-5 cm | 5600 | 2.5 | **48** | 120 | 0.7 | 0.7 | 34000 | 37 | **110** | **380** | 67000 | 150 | 7000 | 930 | 2.3 | **3600** | 4.4 | 60 | 20 | 650 |
| | 0-5 cm | 4000 | 1.6 | **41** | 86 | 0.25 | 0.7 | 34000 | 18 | **81** | 280 | 40000 | 120 | 7500 | 660 | 1.3 | **2700** | 4.8 | 53 | 16 | 430 |
| | 5-10 cm | 4500 | 2.2 | **66** | 150 | 0.6 | 0.7 | 29000 | 33 | **160** | **530** | 120000 | **220** | 6500 | 950 | 3 | **6400** | 5.7 | 51 | 22 | **830** |
| | 5-10 cm | 5400 | 2.1 | **58** | 160 | 0.8 | 1.5 | 30000 | 36 | **190** | **670** | 140000 | **240** | 6000 | 1200 | 3.9 | **8000** | 7.4 | 58 | 24 | **960** |
| | 10-20 cm | 5200 | 2.1 | **69** | 260 | 0.25 | 1.3 | 26000 | 33 | **110** | **680** | 100000 | **280** | 6200 | 1000 | 2.2 | **6100** | 5.2 | 51 | 24 | **930** |
| | 10-20 cm | 4600 | 2.8 | **49** | 130 | 0.25 | 1 | 30000 | 26 | **86** | **420** | 74000 | 180 | 6800 | 770 | 2.5 | **4400** | 4.7 | 51 | 21 | 680 |
| 2292721<br>(fill area) | 0-5 cm | 14000 | 0.5 | 6.2 | 85 | 0.6 | 0.6 | 31000 | 21 | 10 | 25 | 21000 | 33 | 9600 | 580 | 0.5 | 65 | 0.2 | 64 | 32 | 75 |
| | 5-10 cm | 14000 | 0.4 | 7.8 | 90 | 0.7 | 0.4 | 29000 | 20 | 13 | 31 | 21000 | 29 | 9500 | 600 | 0.5 | 180 | 0.3 | 58 | 32 | 70 |
| | 10-20 cm | 14000 | 0.8 | 11 | 100 | 0.7 | 0.7 | 34000 | 23 | 30 | 120 | 27000 | 60 | 10000 | 640 | 0.6 | **1400** | 1.4 | 68 | 33 | 130 |
| | 0-5 cm | 14000 | 0.4 | 9.2 | 100 | 0.7 | 0.4 | 31000 | 21 | 15 | 44 | 22000 | 56 | 9800 | 570 | 0.5 | **310** | 0.3 | 63 | 33 | 110 |
| | 5-10 cm | 14000 | 0.4 | 10 | 100 | 0.7 | 0.6 | 26000 | 23 | 22 | 70 | 23000 | 65 | 8800 | 650 | 0.7 | **620** | 0.8 | 62 | 34 | 140 |
| | 10-20 cm | 14000 | 0.7 | 10 | 100 | 0.7 | 0.3 | 28000 | 24 | 33 | 110 | 24000 | 95 | 9500 | 580 | 0.5 | **1200** | 1.5 | 61 | 35 | 150 |
| 2292721<br>(west of fill area) | 0-5 cm | 11000 | 0.9 | 12 | 100 | 0.6 | 0.9 | 15000 | 18 | 50 | 160 | 20000 | 170 | 7300 | 400 | 0.5 | **1600** | 2 | 46 | 29 | 300 |
| | 5-10 cm | 15000 | 2.1 | 11 | 110 | 0.7 | 0.7 | 13000 | 23 | 33 | 120 | 23000 | 120 | 6300 | 420 | 0.8 | **1200** | 1.5 | 43 | 34 | 180 |
| | 10-20 cm | 15000 | 1.3 | 14 | 150 | 0.9 | 0.7 | 23000 | 37 | 50 | 210 | 28000 | 180 | 8300 | 420 | 0.9 | **2300** | 2.6 | 76 | 37 | 310 |
| | 0-5 cm | 8600 | 1 | 9.8 | 77 | 0.5 | 0.7 | 19000 | 17 | **56** | 160 | 18000 | 200 | 9000 | 420 | 0.5 | **1800** | 2.2 | 44 | 25 | 280 |
| | 5-10 cm | 12000 | 0.8 | 12 | 87 | 0.6 | 0.2 | 12000 | 18 | 37 | 130 | 20000 | 160 | 5900 | 400 | 0.6 | **1400** | 1.6 | 37 | 30 | 180 |
| 2024902<br>(north side) | 0-5 cm | 11000 | 2.1 | 11 | 140 | 0.6 | 0.9 | 32000 | 24 | 31 | 130 | 18000 | 130 | 16000 | 340 | 1.4 | **910** | 1.6 | 120 | 27 | 300 |
| | 0-5 cm | 12000 | 2 | 11 | 170 | 0.7 | 0.9 | 31000 | 24 | 34 | 140 | 20000 | 180 | 16000 | 370 | 1.4 | **940** | 1.4 | 130 | 30 | 320 |
| 2024901<br>(south side) | 0-5 cm | 17000 | 1.4 | 15 | 110 | 0.9 | 1.3 | 18000 | 25 | 40 | 180 | 20000 | 81 | 8700 | 350 | 1.2 | **1400** | 1.8 | 75 | 35 | 220 |
| | 0-5 cm | 18000 | 1.1 | 16 | 120 | 1 | 1.2 | 18000 | 27 | 42 | 180 | 21000 | 93 | 8600 | 360 | 1 | **1400** | 2.2 | 76 | 37 | 240 |
| | 5-10 cm | 18000 | 1.4 | 20 | 110 | 1 | 1 | 18000 | 26 | 43 | 190 | 21000 | 86 | 8700 | 360 | 0.5 | **1500** | 2.8 | 72 | 37 | 230 |
| | 5-10 cm | 17000 | 1.3 | 19 | 110 | 1 | 0.9 | 15000 | 26 | 41 | 190 | 21000 | 89 | 7600 | 350 | 1.4 | **1500** | 1.7 | 64 | 36 | 230 |

## Table 6-4: Results of Chemical Analysis (µg/g) of 2001 Residential Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data in bold and underlined exceed MOE Table A effects-based guideline. na - data not available

| Site/Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2022803<br>(east of drive) | 0-5 cm | 6200 | 1.3 | 14 | 66 | 0.5 | 0.2 | 19000 | 19 | 48 | 170 | 24000 | 160 | 9200 | 400 | 1 | **2100** | 2.1 | 63 | 22 | 250 |
| | 0-5 cm | 6600 | 1.4 | 15 | 79 | 0.5 | 0.9 | 21000 | 22 | **62** | 220 | 29000 | **220** | 10000 | 500 | 1.8 | **2700** | 2.3 | 79 | 25 | 310 |
| | 5-10 cm | 6800 | 1.2 | 16 | 64 | 0.5 | 0.9 | 25000 | 20 | **57** | 200 | 25000 | 150 | 12000 | 460 | 1.4 | **2300** | 2.5 | 66 | 24 | 230 |
| | 5-10 cm | 7100 | 1.1 | 16 | 53 | 0.5 | 1.1 | 21000 | 18 | **56** | 200 | 24000 | 160 | 10000 | 460 | 1.4 | **2000** | 2.3 | 56 | 25 | 240 |
| | 10-15 cm | 8000 | 0.4 | 8 | 52 | 0.5 | 0.4 | 20000 | 13 | 13 | 64 | 13000 | 43 | 7900 | 230 | 0.9 | **600** | 0.7 | 90 | 18 | 100 |
| | 10-15 cm | 7000 | 1.1 | 16 | 53 | 0.5 | 0.9 | 24000 | 22 | **66** | 220 | 29000 | 190 | 12000 | 530 | 1.2 | **2500** | 2.1 | 57 | 27 | 270 |
| 2022804<br>(east yard) | 0-5 cm | 8700 | 1.4 | 17 | 120 | 0.5 | 0.8 | 13000 | 28 | **62** | 230 | 33000 | **320** | 5000 | 530 | 1.1 | **2700** | 2 | 60 | 27 | 400 |
| | 0-5 cm | 12000 | 0.6 | 11 | 110 | 0.5 | 0.7 | 7700 | 20 | 25 | 89 | 23000 | 110 | 4200 | 570 | 0.6 | **880** | 1.2 | 27 | 29 | 210 |
| | 5-10 cm | 7300 | 2.6 | **40** | 170 | 0.6 | 1.1 | 16000 | 40 | **140** | **510** | 67000 | **540** | 4700 | 880 | 2 | **6600** | 5.9 | 64 | 34 | 800 |
| | 5-10 cm | 7600 | 2.1 | **30** | 170 | 0.6 | 1.2 | 16000 | 36 | **110** | **410** | 55000 | **420** | 5400 | 790 | 3.9 | **6400** | 4.2 | 58 | 32 | 670 |
| | 10-20 cm | 6300 | 2.9 | **60** | 200 | 0.6 | 0.9 | 17000 | 42 | **140** | **600** | 70000 | **450** | 3600 | 860 | 3 | **8100** | 5 | 83 | 31 | **920** |
| | 10-20 cm | 6600 | 2.5 | **49** | 180 | 0.6 | 1.6 | 16000 | 48 | **140** | **560** | 70000 | **420** | 3900 | 890 | 3.7 | **7200** | 5.8 | 73 | 32 | **860** |
| 2022805<br>(south back yard) | 0-5 cm | 12000 | 0.5 | 11 | 90 | 0.6 | 0.5 | 17000 | 19 | 28 | 91 | 21000 | 90 | 7700 | 430 | 1 | **910** | 1.5 | 72 | 28 | 160 |
| | 0-5 cm | 10000 | 0.4 | 8.7 | 75 | 0.5 | 0.4 | 14000 | 16 | 21 | 63 | 18000 | 82 | 6300 | 390 | 1 | **580** | 1 | 55 | 26 | 140 |
| | 5-10 cm | 14000 | 0.8 | 12 | 130 | 0.8 | 0.9 | 27000 | 21 | 37 | 130 | 24000 | **210** | 11000 | 440 | 0.6 | **1100** | 1.4 | 94 | 31 | 230 |
| | 5-10 cm | 12000 | 0.9 | 13 | 130 | 0.7 | 0.8 | 23000 | 20 | 34 | 140 | 26000 | 160 | 8600 | 470 | 1.1 | **1200** | 1.3 | 110 | 31 | 250 |
| | 10-15 cm | 12000 | 0.6 | 9.6 | 96 | 0.6 | 0.6 | 22000 | 18 | 28 | 94 | 21000 | 100 | 8100 | 400 | 0.7 | **800** | 1 | 73 | 28 | 160 |
| 2022806<br>(west back yard) | 0-5 cm | 8900 | 2.7 | 73 | 160 | 0.8 | 1.9 | 15000 | 55 | **200** | **840** | 100000 | **720** | 5900 | 1300 | 4.9 | **11000** | 6.9 | 56 | 41 | **1300** |
| | 0-5 cm | 10000 | 0.4 | 8.8 | 87 | 0.5 | 0.7 | 10000 | 16 | 21 | 72 | 20000 | 88 | 5100 | 450 | 0.5 | **660** | 0.9 | 32 | 26 | 160 |
| | 5-10 cm | 9900 | 2.1 | **33** | 160 | 0.7 | 2 | 14000 | 34 | **110** | **410** | 55000 | **420** | 5100 | 800 | 2.1 | **4900** | 3.9 | 49 | 37 | **890** |
| | 5-10 cm | 11000 | 0.8 | 13 | 110 | 0.6 | 0.6 | 13000 | 21 | **55** | 180 | 27000 | 180 | 5200 | 530 | 1.2 | **1900** | 2 | 41 | 31 | 340 |
| | 10-20 cm | 6600 | 2.9 | **83** | 190 | 0.6 | 1.6 | 14000 | 43 | **130** | **660** | 86000 | **620** | 4000 | 1000 | 4.2 | **8100** | 4.8 | 56 | 31 | **1200** |
| | 10-20 cm | 8300 | 1.9 | **30** | 170 | 0.6 | 1 | 17000 | 25 | **72** | **360** | 42000 | **440** | 5500 | 690 | 1.9 | **4100** | 2.7 | 66 | 30 | 560 |
| 2022807<br>(west side yard) | 0-5 cm | 11000 | 1 | 15 | 94 | 0.6 | 0.7 | 9600 | 24 | 43 | 170 | 30000 | 190 | 5000 | 610 | 1.6 | **1800** | 1.7 | 30 | 30 | 320 |
| | 0-5 cm | 11000 | 0.6 | 11 | 91 | 0.5 | 0.5 | 8400 | 20 | 34 | 120 | 26000 | 160 | 4600 | 620 | 1.4 | **1300** | 1.4 | 25 | 29 | 230 |
| | 5-10 cm | 8200 | 1.1 | 16 | 110 | 0.5 | 0.6 | 12000 | 22 | **56** | 190 | 31000 | **240** | 4500 | 480 | 1.2 | **2300** | 2.1 | 42 | 26 | 360 |
| | 5-10 cm | 8800 | 3 | **91** | 160 | 0.9 | 1.1 | 14000 | 59 | **210** | **850** | 120000 | **670** | 5300 | 1500 | 4.8 | **10000** | 6.5 | 52 | 44 | **1400** |
| | 10-20 cm | 8900 | 2.7 | **66** | 160 | 0.8 | 1 | 15000 | 44 | **160** | **770** | 94000 | **550** | 4900 | 1100 | 3.1 | **10000** | 4.9 | 62 | 36 | **1200** |
| | 10-20 cm | 8700 | 2.4 | **85** | 150 | 0.8 | 0.7 | 13000 | 53 | **160** | **780** | 110000 | **580** | 4700 | 1300 | 4.5 | **11000** | 3.8 | 54 | 38 | **1400** |
| <T | | 1000 | 1 | 1 | 5 | 2.5 | 1 | 500 | 5 | 2.5 | 5 | 1000 | 10 | 250 | 25 | 2.5 | 2.5 | 1 | 5 | 5 | 25 |
| ≤W | | 200 | 0.2 | 0.2 | 1 | 0.5 | 0.2 | 100 | 1 | 0.5 | 1 | 200 | 2 | 50 | 5 | 0.5 | 0.5 | 0.2 | 1 | 1 | 5 |

<T = a measurable trace amount; interpret with caution
≤W = no measurable response; less than reported value

## Table 6-5: Results of Chemical Analysis (µg/g) of 2000 Trench Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt,
Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium,
V = vanadium, Zn = zinc. Data underlined and in bold exceed MOE Table A effects-based guideline. <T = a measurable trace amount; interpret with caution
≤W = no measurable response; less than reported value

| Site/Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292641<br>Baseball park, SE corner of Davis & Rodney Sts., near 2nd base | 30 - 35 cm | 25500 | 1.6 | 8.5 | 222 | **1.26** | 0.025 | 53100 | 31.5 | 29.3 | 182 | 27900 | 75.5 | 20400 | 455 | 2.3 | **1500** | <0.3 | 246 | 48.9 | 156 |
| | 30 - 35 cm | 19700 | 1.3 | 9.3 | 160 | 0.98 | 0.025 | 55700 | 24.5 | 28.7 | 191 | 24400 | 77 | 22900 | 499 | 2.2 | **1430** | <0.3 | 282 | 40.5 | 154 |
| | 60 - 65 cm | 24600 | 1.3 | 8.7 | 240 | **1.38** | 0.025 | 74000 | 26.6 | 29.3 | 188 | 27000 | 82.3 | 23900 | 668 | 2.3 | **1740** | <0.3 | 292 | 45.4 | 132 |
| | 60 - 65 cm | 24300 | 2 | 9 | 205 | **1.31** | 0.05 | 67700 | 33.5 | 28.6 | 158 | 29400 | 76.8 | 22800 | 568 | 2.6 | **1540** | <0.3 | 215 | 48.8 | 137 |
| | 100 - 105 cm | 12100 | 2.5 | **33.1** | 84.7 | 0.4 | 0.025 | 16100 | 24.3 | **88.8** | **524** | 38400 | 127 | 4660 | 377 | 2.5 | **6680** | 2.5 | 68.1 | 30.9 | 341 |
| | 100 - 105 cm | 24100 | 1.6 | 12.5 | 179 | **1.23** | 0.025 | 48100 | 29.9 | **50.5** | **440** | 29600 | 85.8 | 18300 | 517 | 2.4 | **3020** | <0.3 | 190 | 48.5 | 166 |
| 2292642<br>Baseball park, SE corner of Davis and Rodney Sts., centre of outfield | 30 - 35 cm | 22400 | 1.4 | 9.9 | 207 | **1.26** | 0.025 | 70200 | 27.5 | 26.6 | 148 | 26600 | 67.3 | 29700 | 408 | 2.5 | **1600** | <0.3 | 336 | 48.1 | 128 |
| | 30 - 35 cm | 22500 | 1.1 | 8.2 | 320 | 1.4 | 0.12 | 84500 | 31.8 | 22.8 | 123 | 24200 | 63.3 | 31200 | 519 | 2.5 | **1290** | <0.3 | 460 | 44 | 107 |
| | 60 - 65 cm | 22700 | 2.1 | 11.2 | 224 | **1.36** | 0.08 | 66200 | 28.2 | 26.8 | 135 | 29800 | 71.3 | 24600 | 601 | 2.6 | **1430** | <0.3 | 263 | 46.5 | 119 |
| | 60 - 65 cm | 18500 | 0.8 | 4.2 | 94.8 | 0.51 | 0.09 | 6320 | 24.5 | 10.8 | 37.1 | 16200 | 24.3 | 4440 | 198 | 1.1 | **304** | <0.3 | 52.8 | 39.7 | 63 |
| | 100 - 105 cm | 20500 | 1.6 | 15.8 | 224 | **1.41** | 0.025 | 62600 | 25 | 32 | 207 | 29600 | 98.8 | 23800 | 574 | 2.6 | **2100** | <0.3 | 226 | 42.5 | 166 |
| | 100 - 105 cm | 10700 | 0.5 | 13.6 | 72.8 | 0.28 | 0.025 | 11100 | 15.7 | 21.8 | 266 | 21400 | 28.9 | 4700 | 246 | 1.4 | **2210** | <0.3 | 54 | 30.5 | 127 |
| 2292643<br>North shoulder of Rodney Street, between Mitchell & Davis Sts. | 30 - 35 cm | 12000 | 3.8 | **37.4** | 118 | 0.97 | 0.025 | 97600 | 38 | 177 | **749** | 53700 | 183 | 39100 | 690 | 3.5 | **9730** | 4.6 | 171 | 41.2 | 436 |
| | 30 - 35 cm | 9020 | 2.9 | **30.7** | 149 | 0.77 | 0.025 | 106000 | 30 | 176 | **699** | 46900 | 148 | 49200 | 597 | 3.2 | **8900** | 4.8 | 130 | 36.2 | 334 |
| | 60 - 65 cm | 12900 | 7.2 | **43.1** | 309 | 2.1 | 3.34 | 18900 | 30.9 | 24.7 | 80.6 | 168000 | 247 | 4050 | 1920 | 4.6 | **204** | <0.3 | 124 | 75.7 | **3190** |
| | 60 - 65 cm | 27000 | 6.5 | 19 | 525 | **4.21** | 2.3 | 84600 | 21.3 | 23.3 | 51.9 | 137000 | 150 | 10700 | 1400 | 2.7 | **384** | <0.3 | 323 | 73 | **3710** |
| | 100 - 105 cm | 20700 | 1.1 | 6.4 | 116 | 0.61 | 0.3 | 14600 | 25.1 | 10.5 | 48.4 | 17500 | 33.7 | 4840 | 191 | 1.6 | **374** | <0.3 | 82.2 | 35.8 | 113 |
| | 100 - 105 cm | 23900 | 0.8 | 2.5 | 121 | 0.67 | 0.13 | 5420 | 28.1 | 10.8 | 4.8 | 17100 | 27.9 | 5500 | 189 | 1 | 66.4 | <0.3 | 39.5 | 42.1 | 81 |
| 2292644<br>NW corner of vacant lot south of Rodney Street between Welland and Fares Sts. | 30 - 35 cm | 2520 | 0.2 | 6.9 | 18.7 | 0.05 | 0.24 | 27800 | 5.86 | 8.68 | 34.9 | 12500 | 25.2 | 7180 | 163 | 1.3 | **364** | <0.3 | 41.7 | 14.1 | 81 |
| | 30 - 35 cm | 3170 | 1.3 | 16.2 | 38 | 0.19 | 0.32 | 29800 | 15.6 | 29.8 | 158 | 33700 | 68.6 | 7340 | 316 | 2.2 | **1650** | 0.5 | 51.5 | 15.6 | 293 |
| | 60 - 65 cm | 2700 | 0.2 | 2.6 | 23.9 | 0.06 | 0.21 | 30600 | 5.14 | 3.77 | 11.7 | 7780 | 18.1 | 7870 | 156 | 1.2 | 102 | <0.3 | 62.6 | 12.5 | 34 |
| | 60 - 65 cm | 3440 | 1.2 | 12.6 | 32.1 | 0.13 | 0.33 | 30400 | 17 | 24.4 | 115 | 31200 | 58.1 | 7940 | 333 | 2.4 | **1310** | <0.3 | 46.6 | 22.6 | 218 |
| | 100 - 105 cm | 2720 | 0.2 | 3.2 | 33.9 | 0.19 | 0.4 | 21600 | 6.13 | 4.2 | 9.6 | 6460 | 4.6 | 1260 | 233 | 3 | 96.9 | <0.3 | 117 | 23.3 | 9 |
| | 100 - 105 cm | 2870 | 0.2 | 4.3 | 47.2 | 0.16 | 0.29 | 25700 | 6.51 | 5.96 | 20.9 | 6930 | 5.3 | 1430 | 279 | 5.2 | **210** | 2.5 | 145 | 21.6 | 28 |
| 2292645<br>NE corner of vacant lot south of Rodney Street between Welland & Fares Sts. | 30 - 35 cm | 3340 | 0.2 | 7.5 | 28.8 | 0.28 | 0.36 | 30700 | 6.88 | 6.08 | 47.6 | 14300 | 20.7 | 7030 | 222 | 5.3 | **289** | <0.3 | 53.2 | 16.2 | 89 |
| | 30 - 35 cm | 3780 | 0.2 | **27.3** | 68.1 | 0.39 | 1.94 | 29100 | 11.7 | 49 | 275 | 41300 | 123 | 6660 | 725 | 6.4 | **3320** | 0.9 | 55.6 | 9.1 | 409 |
| | 60 - 65 cm | 2720 | 0.2 | 3.7 | 16.2 | 0.19 | 0.16 | 30100 | 6.64 | 3.83 | 16.2 | 8740 | 8.1 | 7590 | 161 | 5.4 | 91.7 | <0.3 | 47.7 | 17.3 | 32 |
| | 60 - 65 cm | 2480 | 0.2 | 2.3 | 12.4 | 0.15 | 0.1 | 14900 | 5.13 | 2.86 | 1.2 | 6100 | 4.7 | 6250 | 112 | 4.6 | 14.8 | <0.3 | 28.1 | 13.1 | 13 |
| | 100 - 105 cm | 1420 | 0.2 | 5 | 25.7 | 0.15 | 0.26 | 21800 | 4.04 | 5.51 | 17.9 | 6490 | 6.7 | 2090 | 152 | 4.1 | 185 | <0.3 | 87 | 5.6 | 35 |
| | 100 - 105 cm | 1440 | 0.2 | 3.9 | 23.7 | 0.14 | 0.2 | 22700 | 3.57 | 3.69 | 12.3 | 5710 | 3.4 | 2100 | 133 | 4 | 123 | 0.5 | 97.6 | 6.27 | 24 |

## Table 6-5: Results of Chemical Analysis (µg/g) of 2000 Trench Soil Samples, Port Colborne

Al = aluminum, Sb = antimony, As = arsenic, Ba = barium, Be = beryllium, Cd = cadmium, Ca = calcium, Cr = chromium, Co = cobalt, Cu = copper, Fe = iron, Pb = lead, Mg = magnesium, Mn = manganese, Mo = molybdenum, Ni = nickel, Se = selenium, Sr = strontium, V = vanadium, Zn = zinc. Data underlined and in bold exceed MOE Table A effects-based guideline. <T = a measurable trace amount; interpret with caution

≤W = no measurable response; less than reported value

| Site/Location | Soil Depth | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2292647<br>West trench in park east of Welland Street & north of Nickel Street | 30 - 35 cm | 20400 | 0.2 | 7.9 | 153 | 1.15 | 0.99 | 24900 | 39.8 | 24.6 | 107 | 37300 | 138 | 9100 | 623 | 7 | **516** | <0.3 | 75.2 | 38.3 | 289 |
|  | 30 - 35 cm | 7960 | 0.2 | 13.6 | 117 | 0.82 | 1.46 | 40900 | 54.1 | 29.7 | 167 | 56300 | 124 | 8780 | 1290 | 9.3 | **975** | <0.3 | 96.9 | 13 | 499 |
|  | 60 - 65 cm | 12600 | 9.4 | 17.1 | 307 | **2.49** | 5.88 | 40300 | 122 | **51.5** | 141 |  | **479** | 3770 | 4050 | 12.8 | **558** | 1.4 | 157 | 1.28 | **3410** |
|  | 60 - 65 cm | 10300 | 8 | 12.5 | 282 | **2.11** | 6.17 | 30500 | 94.2 | **52.8** | 151 |  | **520** | 3200 | 3990 | 10.6 | **640** | 0.8 | 126 | 0.74 | **3680** |
|  | 100 - 105 cm | 7070 | 0.2 | 14.6 | 121 | 0.86 | 1.18 | 37100 | 12.5 | 13.4 | 124 | 20900 | 96.7 | 2500 | 343 | 7.2 | **739** | <0.3 | 469 | 21.7 | 173 |
|  | 100 - 105 cm | 4980 | 0.2 | 13.1 | 100 | 0.58 | 0.97 | 28100 | 9 | 12.2 | 85.8 | 14500 | 104 | 1780 | 247 | 6.4 | **727** | <0.3 | 302 | 18.3 | 120 |
| 2292647<br>East trench in park west of Welland Street & north of Nickel Street | 30 - 35 cm | 8740 | 10.5 | **32** | 168 | 1.08 | 3.49 | 53400 | 110 | 47.2 | 134 | 15100 | **335** | 11500 | 3300 | 10.7 | **613** | <0.3 | 224 | 34.4 | **1870** |
|  | 30 - 35 cm | 13100 | 0.8 | 9.7 | 48.7 | 0.74 | 0.47 | 122000 | 27.8 | 15.3 | 58.5 | 18100 | 34.1 | 70400 | 227 | 3.3 | **301** | <0.3 | 72.8 | 33.3 | 59 |
|  | 60 - 65 cm | 10400 | 9.3 | **27.6** | 198 | **1.35** | 4.41 | 54100 | 101 | 47.3 | 132 | 147000 | 344 | 12800 | 3610 | 9.3 | **579** | <0.3 | 199 | 33.7 | **1860** |
|  | 60 - 65 cm | 10400 | 6.7 | 21.3 | 195 | **1.38** | 2.35 | 50100 | 55.9 | 46.2 | 128 | 129000 | 234 | 11000 | 2750 | 5.2 | **862** | <0.3 | 189 | 34.2 | **1380** |
|  | 100 - 105 cm | 16600 | 0.7 | 3.6 | 68.5 | 0.49 | 0.28 | 10600 | 18.8 | 10.3 | 16.7 | 17200 | 33.7 | 5600 | 226 | 1.5 | 97.3 | <0.3 | 26.3 | 33.1 | 76 |
|  | 100 - 105 cm | 15400 | 0.4 | 3.5 | 70.1 | 0.46 | 0.27 | 11600 | 18.7 | 10.5 | 16.9 | 17400 | 42.1 | 6020 | 242 | 1.5 | 107 | <0.3 | 26.7 | 32.9 | 82 |
| 2292648<br>West berm in park west of Welland Street & north of Nickel Street | 0-5 cm | 16600 | 0.8 | 3.2 | 72.1 | 0.51 | 0.3 | 14500 | 19 | 10.2 | 16.2 | 18200 | 37.7 | 6860 | 254 | 1.6 | 89.2 | <0.3 | 30.7 | 33.7 | 77 |
|  | 0-5 cm | 15900 | 0.6 | 4 | 75.4 | 0.49 | 0.28 | 15500 | 18.2 | 10.1 | 16 | 17700 | 43.1 | 7020 | 312 | 1.5 | 90.4 | <0.3 | 30.6 | 32.9 | 74 |
|  | 5-10 cm | 17200 | 1.4 | 4.4 | 84.4 | 0.59 | 0.26 | 27000 | 21 | 11.3 | 15.7 | 20900 | 38.9 | 12000 | 367 | 1.7 | 92 | <0.3 | 44.5 | 34.8 | 79 |
|  | 5-10 cm | 20300 | 1.1 | 4.6 | 109 | 0.74 | 0.28 | 33200 | 23.2 | 12.8 | 16.4 | 23200 | 37.2 | 14100 | 479 | 1.7 | 89.2 | <0.3 | 53.7 | 39.5 | 85 |
|  | 10-15 cm | 24100 | 1.4 | 5.3 | 126 | 0.92 | 0.36 | 30800 | 28.9 | 14.4 | 18.5 | 29000 | 40.7 | 13300 | 482 | 1.8 | 105 | <0.3 | 65.2 | 45.9 | 130 |
|  | 10-15 cm | 16400 | 1 | 3.8 | 92.8 | 0.61 | 0.3 | 32700 | 21.7 | 12.2 | 17.3 | 21100 | 44 | 11900 | 374 | 1.8 | 107 | <0.3 | 54.4 | 33.8 | 100 |
| 2292649<br>East berm in park west of Welland Street & north of Nickel Street | 0-5 cm | 14400 | 0.2 | 1.7 | 71.4 | 0.63 | 0.41 | 11600 | 19.2 | 10.8 | 21.6 | 17300 | 54.9 | 5630 | 257 | 4.9 | 108 | <0.3 | 27.6 | 30.2 | 96 |
|  | 0-5 cm | 14100 | 0.2 | 2.7 | 66.6 | 0.58 | 0.41 | 11200 | 17.4 | 10.9 | 21.3 | 16300 | 52.9 | 5550 | 248 | 4.9 | 115 | <0.3 | 24.4 | 29.6 | 87 |
|  | 5-10 cm | 16200 | 0.2 | 3.1 | 79.3 | 0.71 | 0.39 | 14700 | 20 | 11.4 | 18.3 | 19100 | 45.1 | 7130 | 304 | 5.5 | 102 | <0.3 | 31.5 | 32.3 | 87 |
|  | 5-10 cm | 14100 | 0.2 | 3.7 | 80.9 | 0.65 | 0.45 | 18100 | 19.5 | 11.1 | 21.1 | 18200 | 59.5 | 7590 | 307 | 5.5 | 117 | <0.3 | 34.3 | 27.4 | 105 |
|  | 10-15 cm | 26800 | 0.2 | 2.4 | 173 | **1.29** | 0.44 | 30800 | 33.2 | 16.4 | 23.4 | 29200 | 106 | 15200 | 514 | 6.3 | 98.4 | <0.3 | 62.9 | 48.7 | 118 |
|  | 10-15 cm | 18400 | 0.2 | 4.7 | 124 | 0.92 | 0.49 | 35800 | 25.4 | 14.4 | 30.3 | 23700 | 110 | 14000 | 496 | 6.4 | 135 | <0.3 | 63 | 35.7 | 133 |
|  | 15-20 cm | 19000 | 0.2 | 2.8 | 124 | 0.94 | 0.45 | 33200 | 26.4 | 15.1 | 29.9 | 24600 | 86.7 | 13500 | 447 | 6.3 | 143 | <0.3 | 65.9 | 37.8 | 131 |
|  | 15-20 cm | 25100 | 0.2 | 2.9 | 157 | 1.21 | 0.41 | 33200 | 31.6 | 16.6 | 22 | 30100 | 61.2 | 15100 | 585 | 6.4 | 95.2 | <0.3 | 68.7 | 46.2 | 105 |
| <T |  | 1000 | 1 | 1 | 5 | 2.5 | 1 | 500 | 5 | 2.5 | 5 | 1000 | 10 | 250 | 25 | 2.5 | 2.5 | 1 | 5 | 5 | 25 |
| ≤W |  | 200 | 0.2 | 0.2 | 1 | 0.5 | 0.2 | 100 | 1 | 0.5 | 1 | 200 | 2 | 50 | 5 | 0.5 | 0.5 | 0.2 | 1 | 1 | 5 |

## Table 6-6: Summary of the 2000 Residential Soil Data (0 to 5 cm Depth)

| Element | Concentration (µg/g) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | Median | 10th Percentile | 20th Percentile | 30th Percentile | 40th Percentile | 50th Percentile | 60th Percentile | 70th Percentile | 80th Percentile | 90th Percentile |
| Aluminum | 3,700 | 38,800 | 16,991 | 16,700 | 9,094 | 11,860 | 13,670 | 15,320 | 16,700 | 18,300 | 19,900 | 21,400 | 24,620 |
| Antimony | 0.2 | 23.0 | 1.0 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.7 | 1.3 | 3.0 |
| Arsenic | 1.2 | 350 | 13.5 | 10.8 | 5.4 | 7.1 | 8.3 | 9.3 | 10.8 | 12.7 | 14.4 | 17 | 22 |
| Barium | 22 | 511 | 158 | 149 | 87 | 100 | 119 | 132 | 149 | 164 | 180 | 194 | 240 |
| Beryllium | 0.2 | 2.2 | 0.9 | 0.9 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 | 1.1 | 1.2 | 1.3 |
| Cadmium | 0.23 | 5.08 | 1.19 | 1.09 | 0.48 | 0.64 | 0.81 | 0.96 | 1.09 | 1.25 | 1.43 | 1.67 | 2.07 |
| Calcium | 3,180 | 91,000 | 18,956 | 17,700 | 10,180 | 12,900 | 14,040 | 15,400 | 17,700 | 19,200 | 21,060 | 24,000 | 27,600 |
| Chromium | 8 | 154 | 29 | 28 | 18 | 22 | 25 | 26 | 28 | 30 | 32 | 35 | 38 |
| Cobalt | 5 | 222 | 48 | 38 | 20 | 24 | 28 | 32 | 38 | 44 | 51 | 66 | 84 |
| Copper | 8 | 1,100 | 215 | 174 | 70 | 105 | 130 | 150 | 173 | 210 | 249 | 304 | 400 |
| Iron | 8,820 | 78,000 | 26,378 | 25,200 | 17,995 | 19,845 | 21,540 | 23,200 | 25,100 | 26,680 | 28,800 | 30,780 | 35,920 |
| Lead | 8 | 1350 | 205 | 170 | 78 | 98 | 118 | 114 | 170 | 200 | 238 | 283 | 371 |
| Magnesium | 1,400 | 31,900 | 7,677 | 7,040 | 4,088 | 5,550 | 6,074 | 6,520 | 7,030 | 7,696 | 8,518 | 9,534 | 11,040 |
| Manganese | 160 | 2,030 | 475 | 465 | 336 | 382 | 411 | 440 | 465 | 482 | 505 | 543 | 608 |
| Molybdenum | 0.2 | 12.0 | 4.0 | 4.0 | 1.0 | 2.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 6.0 |
| Nickel | 48 | 10,600 | 2,083 | 1,600 | 489 | 761 | 983 | 1,242 | 1,580 | 1,910 | 2,286 | 3,038 | 4,392 |
| Strontium | 19 | 690 | 74 | 64 | 39 | 46 | 54 | 59 | 64 | 72 | 61 | 92 | 114 |
| Vanadium | 16 | 68 | 36 | 36 | 25 | 29 | 32 | 34 | 36 | 38 | 41 | 44 | 49 |
| Zinc | 30 | 1590 | 341 | 298 | 150 | 189 | 227 | 259 | 298 | 329 | 386 | 482 | 592 |
| Selenium | 1.10 | 10.00 | 1.14 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 1.15 | 0.50 | 1.00 | 2.14 | 3.71 |

Data are µg/g dry weight.
Original data in: Ontario Ministry of the Environment. 2001. *Results of Soil Analysis for all Properties Sampled by the Ministry of the Environment in the Rodney Street Community: Port Colborne (2000 and 2001)*. Standards Development Branch, Report Number SDB-072-3511-2001.
N.B. Does not include the residential properties sampled in 2001, or the 2000 trench samples.

## Table 6-7: Summary of the 2000 Residential Soil Data (5 to 10 cm Depth)

| Element | Concentration (µg/g) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | Median | 10th Percentile | 20th Percentile | 30th Percentile | 40th Percentile | 50th Percentile | 60th Percentile | 70th Percentile | 80th Percentile | 90th Percentile |
| Aluminum | 3,900 | 40,000 | 18,401 | 18,450 | 9,682 | 12,100 | 14,600 | 16,600 | 18,450 | 19,860 | 21,700 | 23,680 | 27,570 |
| Antimony | 0.2 | 34.5 | 1.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.4 | 0.8 | 1.4 | 3 |
| Arsenic | 0.6 | 110 | 15.9 | 12.5 | 5.6 | 7.1 | 8.6 | 10 | 12.5 | 15 | 17.7 | 21.9 | 30 |
| Barium | 19 | 624 | 172 | 156 | 90 | 107 | 128 | 140 | 156 | 174 | 193 | 218 | 274 |
| Beryllium | 0.3 | 2.2 | 1.0 | 1.0 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 |
| Cadmium | 0.03 | 4.3 | 1.22 | 1.09 | 0.4 | 0.6 | 0.78 | 0.91 | 1.09 | 1.27 | 1.5 | 1.8 | 2.2 |
| Calcium | 1,920 | 77,000 | 19,541 | 17,850 | 9,901 | 12,220 | 14,200 | 16,000 | 17,850 | 20,420 | 23,100 | 25,480 | 30,000 |
| Chromium | 9 | 245 | 31 | 30 | 20 | 23 | 26 | 28 | 30 | 32 | 34 | 37 | 41 |
| Cobalt | 5 | 262 | 52 | 40 | 20 | 25 | 30 | 34 | 40 | 48 | 57 | 71 | 96 |
| Copper | 4 | 1,120 | 252 | 200 | 69 | 104 | 130 | 161 | 200 | 237 | 300 | 374 | 486 |
| Iron | 10,100 | 130,000 | 30,462 | 28,000 | 18,338 | 21,400 | 23,700 | 26,000 | 28,000 | 29,960 | 32,170 | 35,680 | 43,180 |
| Lead | 6 | 1,430 | 220 | 172 | 76 | 99 | 120 | 146 | 172 | 206 | 249 | 315 | 409 |
| Magnesium | 1,400 | 21,000 | 7,791 | 7,315 | 4,214 | 5,554 | 6,239 | 6,694 | 7,315 | 7,928 | 8,697 | 9,994 | 11,600 |
| Manganese | 137 | 3,880 | 514 | 483 | 351 | 395 | 433 | 460 | 483 | 517 | 548 | 596 | 680 |
| Molybdenum | 0.1 | 12.0 | 4.0 | 4.0 | 1.0 | 2.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 6.0 |
| Nickel | 35 | 17,000 | 2,624 | 1,800 | 509 | 741 | 1,044 | 1,374 | 1,800 | 2,296 | 2,918 | 3,796 | 5,609 |
| Strontium | 16 | 590 | 76 | 68 | 37 | 46 | 54 | 62 | 68 | 77 | 86 | 97 | 117 |
| Vanadium | 15 | 70 | 38 | 38 | 26 | 29 | 32 | 35 | 38 | 41 | 43 | 46 | 51 |
| Zinc | 23 | 1,440 | 373 | 301 | 140 | 190 | 224 | 259 | 301 | 369 | 441 | 529 | 683 |
| Selenium | 0.10 | 19.40 | 1.31 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.54 | 1.10 | 2.40 | 4.30 |

Data are µg/g dry weight.
Original data in: Ontario Ministry of the Environment. 2001. *Results of Soil Analysis for all Properties Sampled by the Ministry of the Environment in the Rodney Street Community: Port Colborne (2000 and 2001).* Standards Development Branch, Report Number SDB-072-3511-2001.
N.B. Does not include the residential properties sampled in 2001, or the 2000 trench samples.

## Table 6-8: Summary of the 2000 Residential Soil Data (10 to 20 cm Depth)

| Element | Concentraion (µg/g) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | Median | 10th Percentile | 20th Percentile | 30th Percentile | 40th Percentile | 50th Percentile | 60th Percentile | 70th Percentile | 80th Percentile | 90th Percentile |
| Aluminum | 3,200 | 47,300 | 18,403 | 18,600 | 8,888 | 12,000 | 14,210 | 16,400 | 18,600 | 20,000 | 21,700 | 23,920 | 27,830 |
| Antimony | 0.2 | 91.1 | 1.5 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.4 | 0.6 | 0.9 | 1.5 | 3.2 |
| Arsenic | 0.3 | 130 | 18.1 | 15.7 | 6.7 | 8.3 | 10.5 | 13 | 15.7 | 18 | 20.5 | 26.3 | 32 |
| Barium | 30 | 956 | 191 | 168 | 99 | 120 | 138 | 152 | 168 | 186 | 207 | 244 | 293 |
| Beryllium | 0.3 | 4.6 | 1.0 | 1.0 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.5 |
| Cadmium | 0.1 | 35.33 | 1.27 | 1.1 | 0.33 | 0.6 | 0.77 | 0.91 | 1.1 | 1.23 | 1.51 | 1.79 | 2.2 |
| Calcium | 2,880 | 93,400 | 21,907 | 20,900 | 11,770 | 14,580 | 16,610 | 18,800 | 20,900 | 22,740 | 24,800 | 27,960 | 33,230 |
| Chromium | 9 | 183 | 31 | 30 | 20 | 24 | 26 | 28 | 30 | 32 | 34 | 37 | 41 |
| Cobalt | 6 | 214 | 52 | 40 | 22 | 27 | 32 | 36 | 40 | 48 | 57 | 73 | 98 |
| Copper | 8 | 2,720 | 284 | 224 | 88 | 124 | 154 | 190 | 224 | 262 | 331 | 422 | 534 |
| Iron | 12,000 | 77,000 | 31,810 | 30,150 | 20,100 | 23,340 | 25,710 | 27,400 | 30,150 | 32,800 | 35,390 | 39,060 | 46,150 |
| Lead | 20 | 1,800 | 243 | 194 | 79 | 103 | 136 | 164 | 194 | 224 | 260 | 320 | 457 |
| Magnesium | 990 | 21,200 | 7,958 | 73,303 | 4,735 | 5,564 | 6,240 | 6,708 | 7,330 | 8,072 | 8,880 | 9,904 | 11,930 |
| Manganese | 131 | 5,620 | 532 | 495 | 350 | 409 | 445 | 473 | 495 | 526 | 566 | 617 | 682 |
| Molybdenum | 0.0 | 12.0 | 4.0 | 4.0 | 1.0 | 2.0 | 3.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 6.0 |
| Nickel | 38 | 14,000 | 2,929 | 2,190 | 620 | 993 | 1,282 | 1,660 | 2,190 | 2,732 | 3,436 | 4,758 | 6,230 |
| Strontium | 14 | 431 | 87 | 76 | 43 | 54 | 61 | 69 | 76 | 87 | 98 | 111 | 137 |
| Vanadium | 12 | 75 | 38 | 38 | 26 | 29 | 32 | 35 | 38 | 40 | 43 | 46 | 51 |
| Zinc | 52 | 1750 | 397 | 341 | 155 | 197 | 235 | 296 | 341 | 397 | 463 | 572 | 709 |
| Selenium | 0.10 | 8.80 | 1.09 | 0.54 | 0.15 | 0.15 | 0.15 | 0.15 | 0.54 | 0.95 | 1.60 | 2.63 | 4.22 |

Data are µg/g dry weight.
Original data in: Ontario Ministry of the Environment. 2001. *Results of Soil Analysis for all Properties Sampled by the Ministry of the Environment in the Rodney Street Community: Port Colborne (2000 and 2001)*. Standards Development Branch, Report Number SDB-072-3511-2001.
N.B. Does not include the residential properties sampled in 2001, or the 2000 trench samples.

## Table 6-9: Summary of the 2000 Residential Soil Data (All Depths Combined)

| Element | Concentration (µg/g) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | Median | 10th Percentile | 20th Percentile | 30th Percentile | 40th Percentile | 50th Percentile | 60th Percentile | 70th Percentile | 80th Percentile | 90th Percentile |
| Aluminum | 3,200 | 47,300 | 17,850 | 17,800 | 8,990 | 12,000 | 14,100 | 16,000 | 17,800 | 19,500 | 20,920 | 22,900 | 26,600 |
| Antimony | 0.28 | 91 | 1.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.8 | 1.4 | 3.1 |
| Arsenic | 0.3 | 350 | 15.9 | 12.7 | 5.7 | 7.5 | 8.7 | 10.5 | 12.7 | 15 | 17.8 | 21.3 | 29 |
| Barium | 19 | 956 | 173 | 157 | 90 | 109 | 127 | 142 | 157 | 174 | 191 | 217 | 270 |
| Beryllium | 0.2 | 4.6 | 1 | 1 | 0.6 | 0.7 | 0.8 | 0.9 | 1 | 1.1 | 1.2 | 1.3 | 1.4 |
| Cadmium | 0.1 | 35 | 1.2 | 1.1 | 0.4 | 0.6 | 0.78 | 0.93 | 1.09 | 1.25 | 1.47 | 1.74 | 2.16 |
| Calcium | 1,920 | 93,400 | 20,100 | 18,700 | 10,300 | 13,200 | 15,000 | 16,700 | 18,700 | 20,900 | 23,300 | 25,600 | 30,540 |
| Chromium | 6 | 245 | 30 | 29 | 20 | 23 | 26 | 28 | 29 | 31 | 34 | 36 | 40 |
| Cobalt | 3.5 | 262 | 51 | 40 | 20 | 25 | 30 | 34 | 40 | 47 | 55 | 70 | 91 |
| Copper | 4.4 | 2720 | 250 | 200 | 73 | 109 | 137 | 164 | 200 | 237 | 290 | 367 | 471 |
| Iron | 8,620 | 130,000 | 29,500 | 27,300 | 18,480 | 21,200 | 23,500 | 25,700 | 27,300 | 29,700 | 32,100 | 35,700 | 42,280 |
| Lead | 6 | 1,800 | 222 | 179 | 77 | 99 | 122 | 151 | 179 | 208 | 249 | 302 | 406 |
| Magnesium | 990 | 31,900 | 7,780 | 7,220 | 4,376 | 5,544 | 6,190 | 6,650 | 7,220 | 7,916 | 8,720 | 9,828 | 11,530 |
| Manganese | 131 | 5,620 | 506 | 480 | 344 | 392 | 430 | 459 | 480 | 501 | 540 | 588 | 664 |
| Molybdenum | 0.2 | 12.0 | 4.0 | 4.0 | 1.0 | 2.0 | 3.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 6.0 |
| Nickel | 35 | 17,000 | 2,544 | 1,800 | 543 | 808 | 1,090 | 1,414 | 1,800 | 2,280 | 2,880 | 3,900 | 5,588 |
| Strontium | 14 | 690 | 79 | 69 | 39 | 49 | 56 | 63 | 69 | 78 | 88 | 100 | 123 |
| Vanadium | 11 | 75 | 37 | 37 | 25 | 29 | 32 | 35 | 37 | 40 | 42 | 45 | 50 |
| Zinc | 23 | 1,750 | 369 | 314 | 146 | 190 | 227 | 266 | 314 | 363 | 428 | 522 | 561 |
| Selenium | 0.10 | 19.40 | 1.29 | 0.29 | 0.15 | 0.15 | 0.15 | 0.15 | 0.29 | 0.68 | 1.26 | 2.40 | 4.10 |

Data are µg/g dry weight.
Original data in: Ontario Ministry of the Environment. 2001. *Results of Soil Analysis for all Properties Sampled by the Ministry of the Environment in the Rodney Street Community: Port Colborne (2000 and 2001).* Standards Development Branch, Report Number SDB-072-3511-2001.
N.B. Does not include the residential properties sampled in 2001, or the 2000 trench samples.

## Table 6-10: Samples from Port Colborne Submitted for pH in Distilled Water

| Sample ID | Soil pH (Run 1) | Soil pH (Run 2) | Soil pH (Mean) | Soil depth (cm) | Site / Location |
|---|---|---|---|---|---|
| 800 | 7.18 | 7.18 | 7.18 | 5 | 2292547 |
| 805 | 7.11 | 7.09 | 7.1 | 293 | 2292548 |
| 824 | 7.11 | 7.05 | 7.08 | 5 | 2292555 |
| 854 | 7.22 | 7.27 | 7.25 | 5 | 2292561 |
| 858 | 7.42 | 7.37 | 7.4 | 130 | 2292562 |
| 946 | 7.48 | 7.52 | 7.5 | 293 | 2292583 |
| 947 | 7.03 | 6.99 | 7.01 | 5 | 2292640 |
| 952 | 7.14 | 7.19 | 7.17 | 5 | 2292484 |
| 956 | 7.19 | 7.21 | 7.2 | 130 | 2292485 |
| 1019 | 7.42 | 7.37 | 7.39 | 293 | 2292502 |
| 1020 | 7.13 | 7.13 | 7.13 | 5 | 2292503 |
| 1059 | 7.01 | 7.03 | 7.02 | 5 | 2292516 |
| 1134 | 7.26 | 7.26 | 7.26 | 5 | 2292537 |
| 1139 | 7.29 | 7.32 | 7.31 | 293 | 2292538 |
| 1330 | 7.36 | 7.37 | 7.36 | 5 | 2292584 |
| 1334 | 7.25 | 7.35 | 7.3 | 130 | 2292585 |
| 1373 | 7.56 | 7.61 | 7.58 | 130 | 2292595 |
| 1375 | 7.51 | 7.51 | 7.51 | 5 | 2292596 |
| 1379 | 7.29 | 7.21 | 7.25 | 130 | 2292597 |
| 1381 | 7.09 | 7.1 | 7.09 | 5 | 2292598 |
| 3341 | 7.38 | 7.37 | 7.37 | 5 | 2292410 |
| 3346 | 7.61 | 7.7 | 7.65 | 293 | 2292411 |
| 3814 | 7.22 | 7.3 | 7.26 | 130 | 2292376 |
| 3816 | 6.89 | 6.88 | 6.88 | 5 | 2292377 |
| 3834 | 7.66 | 7.65 | 7.65 | 293 | Rodney/Fares St |
| 3892 | 7.11 | 7.09 | 7.1 | 5 | 2292473 |
| 5182 | 7.25 | 7.28 | 7.26 | 5 | 2292327 |
| 5187 | 7.76 | 7.75 | 7.75 | 293 | 2292328 |
| 5252 | 6.98 | 6.99 | 6.98 | 130 | 2292445 |
| 5313 | 7.58 | 7.63 | 7.6 | 293 | 2292449 |
| 5315 | 6.95 | 6.85 | 6.9 | 130 | 2292450 |
| 5361 | 7.23 | 7.24 | 7.23 | 130 | 2292321 |
| 5363 | 7.21 | 7.26 | 7.23 | 5 | 2292322 |
| 5390 | 7.28 | 7.31 | 7.29 | 5 | 2292470 |
| 5404 | 7.52 | 7.61 | 7.57 | 293 | 2292471 |
| 5407 | 7.36 | 7.38 | 7.37 | 293 | 2292471 |

## Table 7-1: Results of T-Test of Mean Soil Concentration by Sample Depth

| Element | Statistical Results[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean Concentration[2] | | | t-statistic (p<)[3] | | | | | |
| | 0-5 cm | 5-10 cm | 10-20 cm | 0-5 vs 5-10 cm | | 0-5 vs 10-20cm | | 5-10 vs-20 cm | |
| Aluminum | 16991 | 18401 | 18403 | -3.2574 | (0.0011) | -3.1663 | (0.0020) | 0.0149 | (0.9959) |
| Antimony | 1 | 1.2 | 1.5 | -1.1543 | (0.2474) | -1.5724 | (0.1098) | -0.8254 | (0.4080) |
| Arsenic | 13.5 | 15.9 | 18.1 | -2.2994 | (0.0220) | -4.4001 | 0.0000 | -2.5112 | (0.0104) |
| Barium | 158 | 172 | 191 | -2.8278 | (0.0047) | -5.6975 | 0.0000 | -2.9428 | (0.0031) |
| Beryllium | 0.9 | 1 | 1 | -3.8549 | (0.0001) | -5.2776 | 0.0000 | -1.6369 | (0.0978) |
| Cadmium | 1.19 | 1.22 | 1.27 | -0.6793 | (0.4765) | -0.9091 | (0.3722) | -0.5387 | (0.5988) |
| Calcium | 18956 | 19541 | 21907 | -0.9532 | (0.3378) | -4.7149 | 0.0000 | -3.7339 | (0.0001) |
| Chromium | 29 | 31 | 31 | -2.1051 | (0.0354) | -2.6679 | (0.0070) | -0.3315 | (0.7185) |
| Cobalt | 48 | 52 | 52 | -1.7103 | (0.0870) | -1.5069 | (0.1277) | 0.3559 | (0.7649) |
| Copper | 215 | 252 | 284 | -3.2796 | (0.0010) | -5.3681 | 0.0000 | -2.1873 | (0.0256) |
| Iron | 26378 | 30462 | 31810 | -5.3429 | 0.0000 | -8.5761 | 0.0000 | -1.5908 | (0.0965) |
| Lead | 205 | 220 | 243 | -1.3927 | (0.1646) | -3.2321 | (0.0011) | -1.8418 | (0.0650) |
| Magnesium | 7677 | 7791 | 7958 | -0.5280 | (0.5896) | -1.3089 | (0.2082) | -0.8064 | (0.4212) |
| Manganese | 475 | 514 | 532 | -3.0824 | (0.0020) | -3.6595 | (0.0002) | -1.0394 | (0.2916) |
| Molybdenum | 4 | 4 | 4 | -0.4963 | (0.6183) | 0.1824 | (0.8623) | 0.6612 | (0.5178) |
| Nickel | 2083 | 2624 | 2929 | -3.6226 | 0.0000 | -5.8776 | 0.0000 | -1.7056 | (0.0727) |
| Strontium | 74 | 76 | 87 | -0.6432 | (0.5240) | -3.9244 | 0.0000 | -3.4480 | (0.0005) |
| Vanadium | 36 | 38 | 38 | -2.8501 | (0.0040) | -2.1703 | (0.0302) | 0.6334 | (0.5355) |
| Zinc | 341 | 373 | 397 | -2.2054 | (0.0275) | -3.8239 | (0.0001) | -1.4892 | (0.1296) |
| Selenium | 1.14 | 1.31 | 1.39 | -1.3217 | (0.1860) | -2.1826 | (0.0260) | -0.6135 | (0.5240) |

1. Statistics calculated using MicroSoft Excel.
2. Mean of all samples from each depth, µg/g dry weight.
3. Two-Tailed t-test, assuming unequal variance.

N.B. Does not include the residential properties sampled in 2001.

## Table 7-2: Results of Pearson Products Correlation Test on the Soil Data from all Residential Properties and the Trenches

| | Al | Sb | As | Ba | Be | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | Se | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 1.00 | | | | | | | | | | | | | | | | | | | |
| Antimony | 0.03 | 1.00 | | | | | | | | | | | | | | | | | | |
| Arsenic | -0.19 | 0.16 | 1.00 | | | | | | | | | | | | | | | | | |
| Barium | 0.35 | 0.22 | 0.20 | 1.00 | | | | | | | | | | | | | | | | |
| Beryllium | 0.79 | 0.10 | -0.03 | 0.60 | 1.00 | | | | | | | | | | | | | | | |
| Cadmium | 0.16 | 0.14 | 0.12 | 0.44 | 0.28 | 1.00 | | | | | | | | | | | | | | |
| Calcium | 0.11 | 0.09 | 0.01 | 0.34 | 0.28 | 0.13 | 1.00 | | | | | | | | | | | | | |
| Chromium | 0.45 | 0.11 | 0.34 | 0.47 | 0.52 | 0.26 | 0.14 | 1.00 | | | | | | | | | | | | |
| Cobalt | -0.04 | 0.09 | 0.56 | 0.31 | 0.11 | 0.27 | 0.07 | 0.36 | 1.00 | | | | | | | | | | | |
| Copper | -0.06 | 0.16 | 0.56 | 0.46 | 0.16 | 0.33 | 0.14 | 0.37 | 0.84 | 1.00 | | | | | | | | | | |
| Iron | 0.03 | 0.15 | 0.59 | 0.34 | 0.17 | 0.20 | 0.14 | 0.41 | 0.75 | 0.71 | 1.00 | | | | | | | | | |
| Lead | -0.01 | 0.38 | 0.28 | 0.74 | 0.29 | 0.41 | 0.27 | 0.30 | 0.36 | 0.50 | 0.37 | 1.00 | | | | | | | | |
| Magnesium | 0.44 | 0.04 | -0.16 | 0.21 | 0.40 | 0.10 | 0.69 | 0.23 | 0.02 | 0.00 | 0.02 | 0.05 | 1.00 | | | | | | | |
| Manganese | 0.08 | 0.09 | 0.25 | 0.23 | 0.21 | 0.11 | 0.25 | 0.23 | 0.34 | 0.31 | 0.49 | 0.18 | 0.15 | 1.00 | | | | | | |
| Molybdenum | 0.25 | 0.04 | -0.15 | 0.20 | 0.32 | 0.19 | 0.17 | 0.16 | -0.09 | -0.05 | -0.03 | 0.12 | 0.25 | 0.14 | 1.00 | | | | | |
| Nickel | -0.11 | 0.10 | 0.60 | 0.33 | 0.08 | 0.29 | 0.08 | 0.33 | 0.93 | 0.87 | 0.82 | 0.41 | -0.05 | 0.35 | -0.12 | 1.00 | | | | |
| Selenium | -0.40 | 0.11 | 0.56 | 0.09 | -0.23 | 0.10 | 0.01 | 0.13 | 0.73 | 0.66 | 0.68 | 0.26 | -0.19 | 0.27 | -0.28 | 0.77 | 1.00 | | | |
| Strontium | 0.07 | 0.14 | 0.09 | 0.44 | 0.33 | 0.18 | 0.67 | 0.20 | 0.08 | 0.19 | 0.16 | 0.36 | 0.30 | 0.12 | 0.10 | 0.11 | 0.07 | 1.00 | | |
| Vanadium | 0.89 | 0.02 | -0.06 | 0.37 | 0.75 | 0.13 | 0.08 | 0.49 | 0.09 | 0.04 | 0.13 | 0.03 | 0.44 | 0.11 | 0.15 | -0.01 | -0.26 | 0.08 | 1.00 | |
| Zinc | -0.10 | 0.23 | 0.50 | 0.67 | 0.23 | 0.42 | 0.21 | 0.42 | 0.66 | 0.77 | 0.65 | 0.75 | -0.03 | 0.30 | 0.02 | 0.71 | 0.57 | 0.34 | 0.00 | 1.00 |

$p<0.05$ @ $r=0.08$, df=1300+.

N.B. Does not include the residential properties sampled in 2001.

**Table 7-3: Soil Metal Levels Observed Around Selected Industries in Ontario**

| Location and Type of Source | Soil Concentration in µg/g* | | | | | | |
|---|---|---|---|---|---|---|---|
| | Iron | Nickel | Copper | Cobalt | Arsenic | Lead | Zinc |
| Welland: specialty steel manufacturer[1] | 24500 | 139 | 32 | 11 | 8.5 | 67 | 179 |
| Hamilton: steel manufacturer[2] | 25500 | 32 | 28 | NA | 4 | 49 | 118 |
| Wawa: Iron sintering[3] | 95000 | 13 | 35 | 6.8 | 273 | 58 | NA |
| Ottawa: Iron foundry[4] | 34000 | 32 | 32 | NA | NA | 40 | 131 |
| Cambridge: Iron Foundry[5] | 15200 | 13 | 21 | 6 | NA | 67 | 183 |
| Sudbury: Nickel and copper mining, smelting, refining[6] | 80000 | 2300 | 2800 | 788 | 510 | 1000 | 270 |
| Port Colborne: 90th percentile from the Rodney Street community | 42280 | 5588 | 471 | 91 | 29 | 406 | NA |

* MOE investigations, data from selected sites believed to be directly impacted by the source.
1. Atlas Specialty Steel, 1993 and 1995.
2. Stelco, 1976.
3. Algoma Ore Division, 1998.
4. Ivaco, 1985 and 1987.
5. Crowe Foundry, 1992.
6. Inco/Falconbridge, 1997 and 2000.

NA data not available or not evaluated.

**Table 8-1: Ratios of Nickel, Copper and Cobalt from Three Areas in Port Colborne**

| Area | Mean Soil Metal Concentration (µg/g) | | | Metal Soil Ratios | |
|---|---|---|---|---|---|
| | Ni | Cu | Co | Ni:Cu | Ni:Co |
| NE of Inco[1] | 1809 | 182 | 32 | 9.9:1 | 56:1 |
| Rodney St. Community[2] | 2545 | 250 | 50 | 10.1:1 | 51:1 |
| Trench Samples[3] | 1401 | 148 | 32 | 9.5:1 | 44:1 |
| Natural Background[4] | 43 | 85 | 21 | 0.5:1 | 2.0:1 |

1 - mean of 8 1998/1999 MOE sample sites to the NE of Inco in the maximum deposition zone.
2 - mean of all Rodney Street Residential Community samples (not including 2001 samples).
3 - mean of all trench samples, excluding the park berms.
4 - MOE Table F (MOE 1997).

## Appendix 1- Part A

### Derivation and Significance of the MOE Soil Remediation Criteria (Clean-up Guidelines)

The MOE soil clean-up *Guidelines* have been developed to provide guidance for cleaning up contaminated soil. The *Guidelines* are not legislated Regulations. Also, the *Guidelines* are not action levels, in that an exceedence does not automatically mean that a clean-up must be conducted. The *Guidelines* were prepared to help industrial property owners decide how to clean-up contaminated soil when property is sold and/or the land use changes. Most municipalities insist that contaminated soil is cleaned up according to the MOE *Guidelines* before they will approve a zoning change for redevelopment, therefore, even though the *Guideline* is voluntary most industrial property owners and developers are obliged to use it. For example, the owner of an industrial property who plans to sell the land to a developer who intends to build residential housing can use the *Guideline* to clean up the soil to meet the residential land-use criteria. In this way previously contaminated industrial land can be re-used for residential housing without concern for adverse environmental effects.

The *Guideline* contains a series of Tables (A through F), each having criteria for soil texture, soil depth, and ground water use for various land-use categories (ie., agricultural, residential, industrial). Table F *criteria* reflect the upper range of background concentrations for soil in Ontario. An exceedence of Table F indicates the likely presence of a contaminant source. Tables A through E *criteria* are effects-based and are set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. The *Guideline criteria* take into consideration the potential for adverse effects through direct contact, and through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, the *Guideline criteria* may not ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

If the decision is made that remedial action is needed, the *criteria* in Tables A to F of the *Guideline* can be used as clean-up targets. In some cases, because of economic or practical reasons, it may not be possible to clean up a site using the generic *criteria* in Tables A to F. The *Guideline* provides a process, called a *site specific risk assessment*, which is used to evaluate the soil contamination with respect to conditions that are unique to the contaminated site. In a *site specific risk assessment* the proponent examines all the potential pathways through which the contamination may impact the environment and must demonstrate that because of conditions unique to that site the environment and human health will not be adversely effected if contamination above the generic *criteria* in Table A to E is left in place.

When contamination is present and a change in land use is not planned, for example residential properties and public green spaces near a pollution source, the *Guideline* may be used in making decisions about the need for remediation. This is different from the previously described situation where a company that caused contamination on their own property decides to clean up the soil, usually at the insistence of the municipality who will not approve a zoning change unless remediation is conducted. Decisions on the need to undertake remedial action when the *Guideline criteria* are exceeded and where the land use is not changing are made on a site by site basis using *site specific risk assessment* principals and are usually contingent on the contaminants having caused an adverse environmental effect or there is a demonstrated likelihood that the contamination may cause an adverse effect. Because of the long history of industrial operation and our practice of living close to our work place the soil in many communities in Ontario is contaminated above the effects-based *criteria* in the MOE *Guidelines*. In practice, remediation of contaminated soil on privately owned residential property and public green spaces has only been conducted in communities when the potential for adverse health effects has been demonstrated.

The soil clean-up *Guidelines* were developed from published US EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. The development of these clean-up *Guidelines* is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing *Guidelines*.

For more information on the MOE's soil clean-up *Guidelines* please refer to the *Guideline for Use at Contaminated Sites in Ontario. Revised February 1997*, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-6114-3. This document is also available on the MOE web site at www.ene.gov.on.ca, under *Contaminated Sites: Clean-up Guideline*.

## Appendix 2 - Part A
## Derivation and Significance of the MOE Soil Background Concentrations (Soil Clean-up Guideline - Table F)

The Table F criteria in the MOE *Guideline for Use at Contaminated Sites in Ontario* represent the expected background range of various chemicals in soil in Ontario. Ontario Typical Ranges (OTR) were derived from a province wide soil sampling program conducted to determine the distribution of chemical concentrations resulting from natural geological processes and normal human activity in surface soil in Ontario remote from the influence of known point sources of pollution. OTRs are developed for several land use categories.

OTRs are based on the analytical data from pre-defined sampling, processing and analytical protocols. Complete details on the OTR development process can be found in the MOE report "*Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow*", MOEE 1993. This report describes the development of the OTR$_{98}$, which represents 98% of the data in the OTR distribution. From a statistical aspect, this is equivalent to the mean plus two standard deviations of a normally distributed population.

A review of the OTR database indicated that a high degree of sampling variability can occur at any given site when concentrations are at background levels, especially when sampling for organic contaminants. Therefore, replicate sampling would be necessary to address variability due to sampling, as well as analytical variability. In order to minimise costly replicate sampling and analysis to proponents in situations where there is little or no danger of effects, the Table F soil background criteria were set at a value equal to the OTR$_{98}$ plus two coefficients of variation (OTR$_{98}$ + 2CVws). The coefficient of variation, in this context, is the average "within site" sampling variability around the OTR$_{98}$, expressed as a percent coefficient of variability (CVws). This was calculated by taking the average of the "within site" coefficients of variation of all points between the OTR$_{98}$ upper and lower confidence limits (MOEE, 1993). The percent value of 2CVws is converted to an absolute value and added to the OTR$_{98}$, which becomes the Table F criterion. If the chemical concentration in a single sample is above Table F (OTR$_{98}$ + 2CVws), one can be certain (with 97.5% confidence) that the OTR$_{98}$ has been exceeded for that chemical.

Rural parkland OTR$_{98}$ values were the basis for the Table F soil background concentrations for the agricultural land use category while urban parkland OTR$_{98}$ values were the basis for the other land use categories. The term "urban" is defined here as any property that lies within an area that is fully serviced by both municipal water and sewage systems.

Reference

*Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags, and Snow*. MOEE Report Number HCB-151-3512-93, PIBs Number 2792, ISBN 0-778-1979-1.

# Part A

# Soil Contaminant Contour Maps

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## 11.0 Methodology for Producing Surfer/ArcView Soil Contaminant Contour Maps

### 11.1 Software Utilized

Two software packages were used to generate the maps. The data analysis and creation of the concentration contours was done using *Surfer Version 7.00 for Windows* by Golden Software Inc. The output from Surfer was imported into *ArcView GIS Version 3.1* by Environmental Systems Research Institute, Inc., and combined with base maps, roads and properties, to produce the final maps. The base map data was obtained from the City of Port Colborne, Public Works Department.

### 11.2 Data Used

For the contour maps produced in this report, all sampling stations collected south of Louis Street in 2000 as part of the intensive sampling of the Rodney Street community or as individual complaint investigations, were used to generate the contours.

### 11.3 Mapping Process

The process involved in creating the maps was to analyze the data and create the desired contours using the Surfer program. The individual contours were exported from Surfer as ESRI Shape files. The polygon portion of the Shape files were imported into ArcView GIS and modified to remove polygon holes created by the export process. The resulting polygons were combined with the street base maps, and the station locations were imported from the Phytotoxicology Information Management System (PIMS). Layouts were then created to include a legend, labels, scale and compass, and printed for the report.

### 11.4 Surfer

For all data sets, a Krigging gridding method was used and the search option was set to use all data. For all contours, smoothing was set at high. All co-ordinates were in Universal Trans Mercator (UTM) Easting and Northing. Where duplicate or triplicate samples existed for a sampling location the program was set to use the average of the results.

### 11. 5 Surfer Settings

| **Grid Line Geometry** | | | | |
|---|---|---|---|---|
| | **Minimum** | **Maximum** | **Spacing** | **# of Lines** |
| **X Axis** (Easting) | 643185 m | 643527 m | 3 m | 115 |
| **Y Axis** (Northing) | 4748834 m | 4749383 m | 3 m | 184 |
| Duplicates - averaged<br>Matrix Smoothing - none | | | | |

## 11.6 ArcView

### 11.6.1 Station Map

A base map was created by importing the Autocad DXF files provided by the City of Port Colborne, Works Department and converting to ArcView Shape files. Only the road, rail lines, property boundaries and building foot prints layers were turned on. To this was added all of the stations sampled in 2000 by importing the station co-ordinates and related information from the PIMS database.

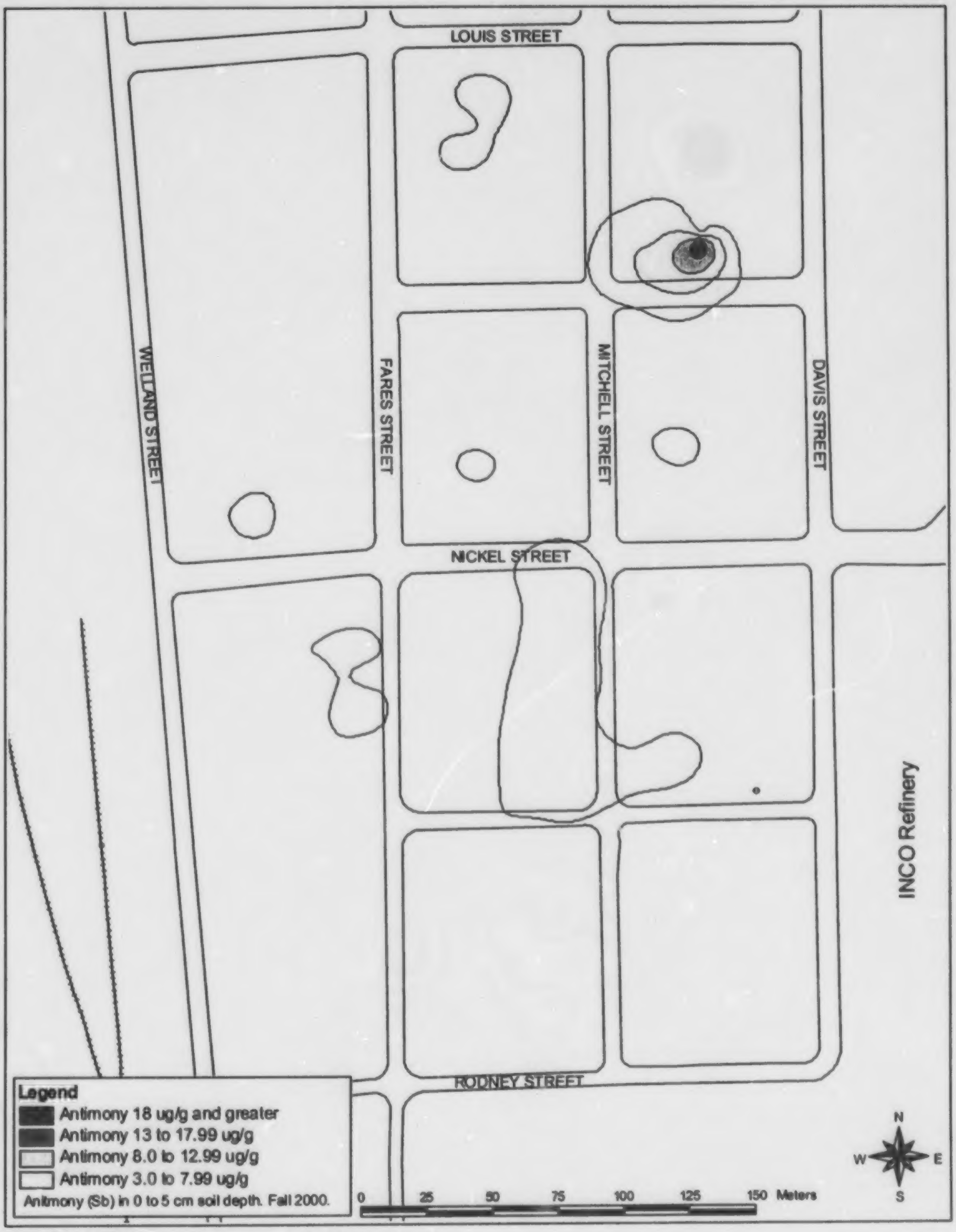
### 11.6.2 Contour Maps

The street layer of the station map was used as the underlying map for all contour maps. Property boundaries, building foot prints and street numbers were not included. The polygons for each contour interval were imported into ArcView as individual shape files from Surfer. Any polygon holes were removed and combined with the other contour intervals. Grey scales were used to differentiate contours for printing purposes.

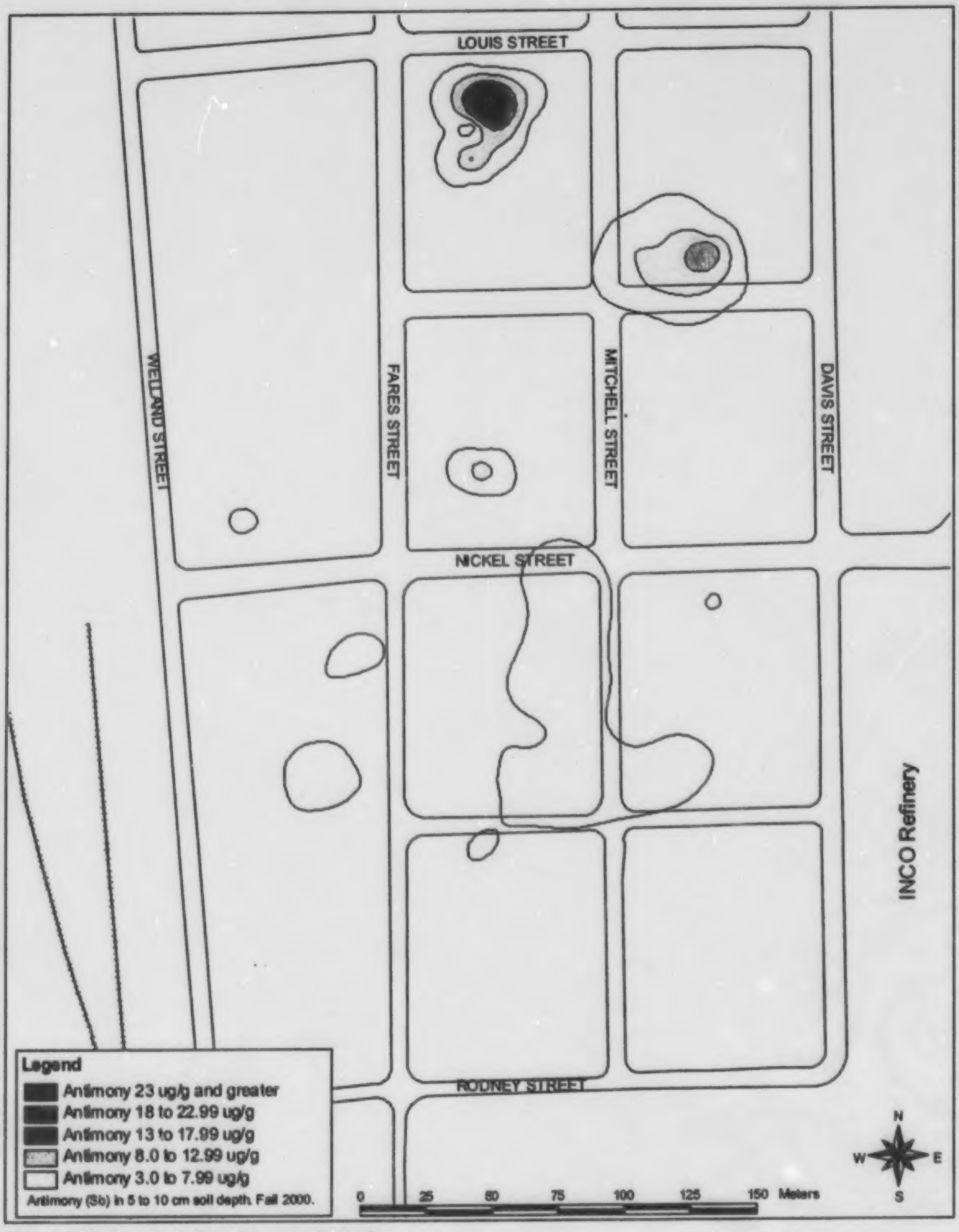
### 11.6.3 Final Maps

A separate ArcView layout was produced for each of the maps and consisted of a base map, contour polygons, scale, compass and legend. Sampling stations were included on the contour polygons maps. These layouts were imported into the report.

## 11.7 Maps


LOUIS STREET
WELLAND STREET
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Antimony 18 ug/g and greater
Antimony 13 to 17.99 ug/g
Antimony 8.0 to 12.99 ug/g
Antimony 3.0 to 7.99 ug/g
Antimony (Sb) in 0 to 5 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
W
E
S

Map A1: Antimony in 0 to 5 cm soil depth.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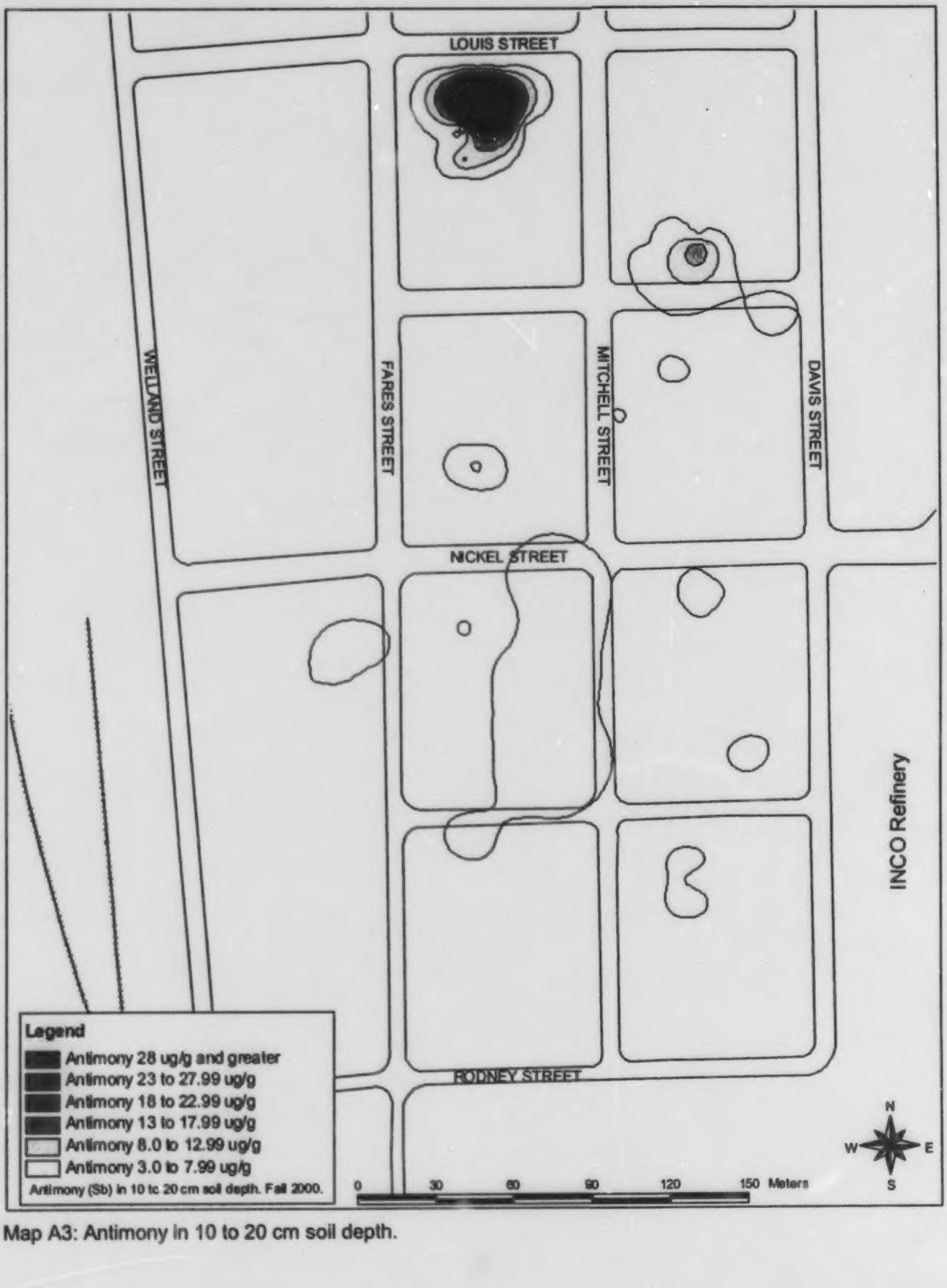
NICKEL STREET
RODNEY STREET
WELLAND STREET
FARES STREET
MITCHELL STREET
DAVIS STREET
INCO Refinery
Legend
Antimony 23 ug/g and greater
Antimony 18 to 22.99 ug/g
Antimony 13 to 17.99 ug/g
Antimony 8.0 to 12.99 ug/g
Antimony 3.0 to 7.99 ug/g
Antimony (Sb) in 5 to 10 cm soil depth. Fall 2000.
0
25
50
75
100
125
150
Meters
N
W
E
S

Map A2: Antimony in 5 to 10 cm soil depth.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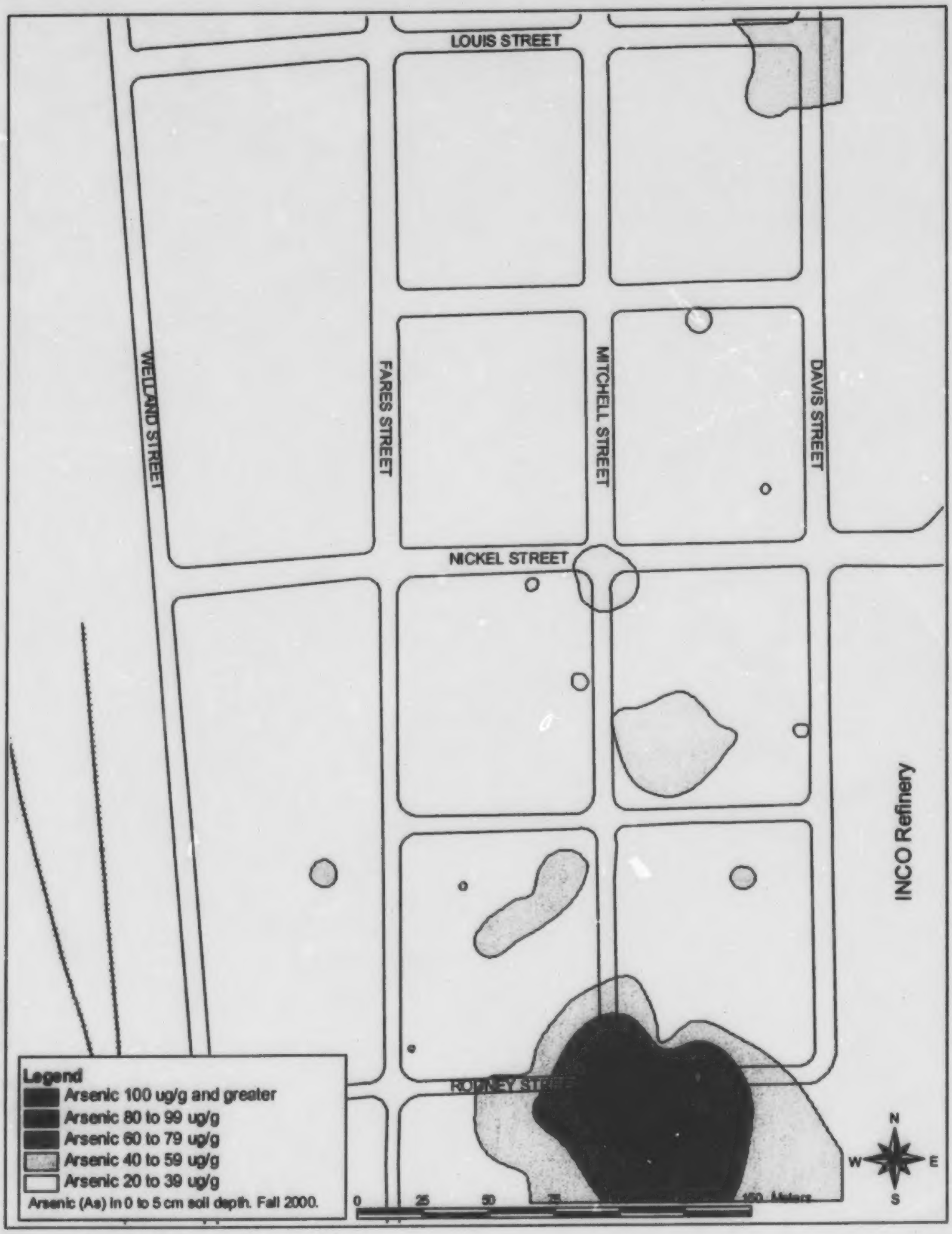
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Antimony 28 ug/g and greater
Antimony 23 to 27.99 ug/g
Antimony 18 to 22.99 ug/g
Antimony 13 to 17.99 ug/g
Antimony 8.0 to 12.99 ug/g
Antimony 3.0 to 7.99 ug/g
Antimony (Sb) in 10 to 20 cm soil depth. Fall 2000.
0
30
60
90
120
150 Meters
N
W
E
S

Map A3: Antimony in 10 to 20 cm soil depth.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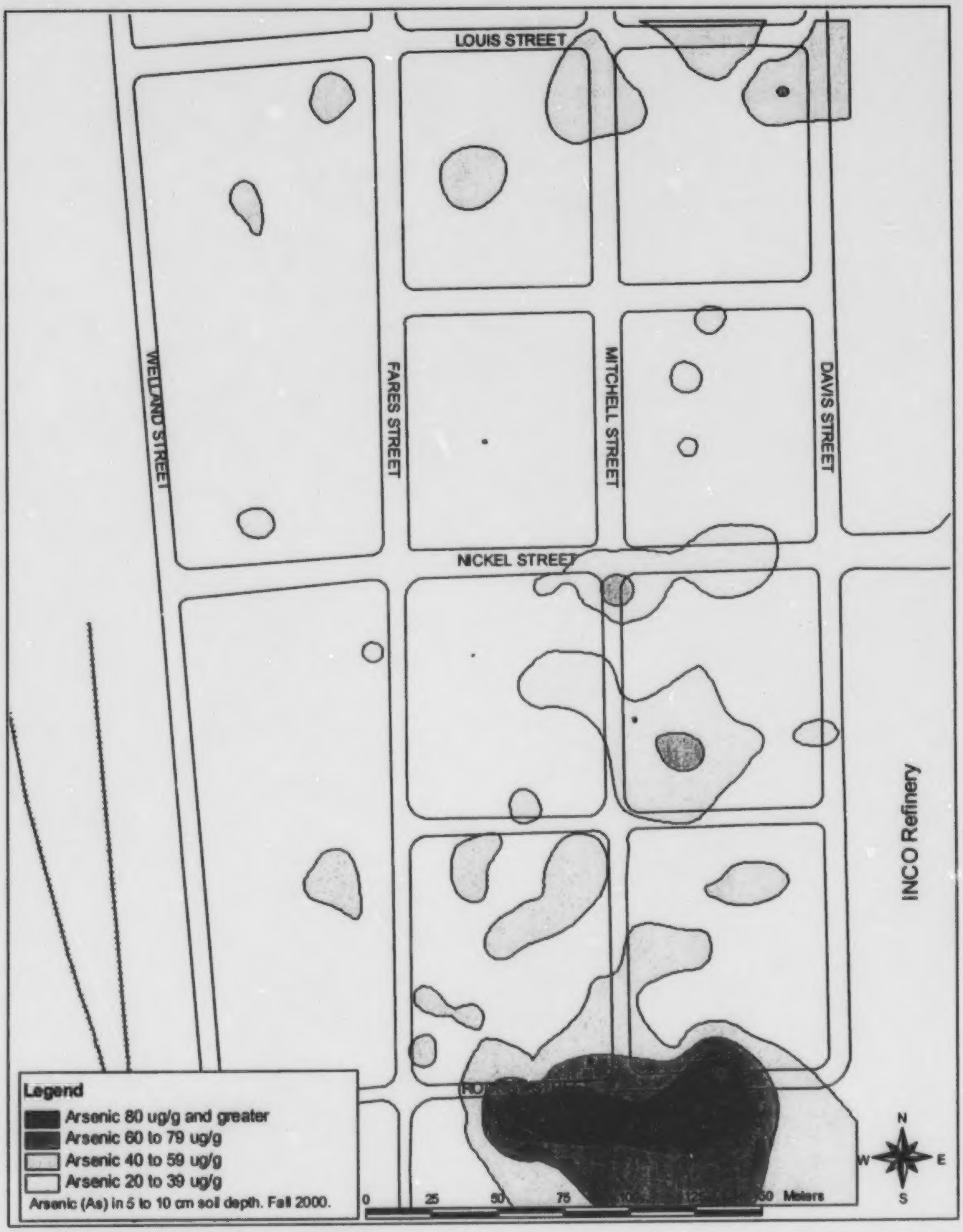
WELLAND STREET
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
N
W
E
S
0
25
50
75
150 Meters
Legend
Arsenic 100 ug/g and greater
Arsenic 80 to 99 ug/g
Arsenic 60 to 79 ug/g
Arsenic 40 to 59 ug/g
Arsenic 20 to 39 ug/g
Arsenic (As) in 0 to 5 cm soil depth. Fall 2000.

Map A4: Arsenic in 0 to 5 cm soil depth.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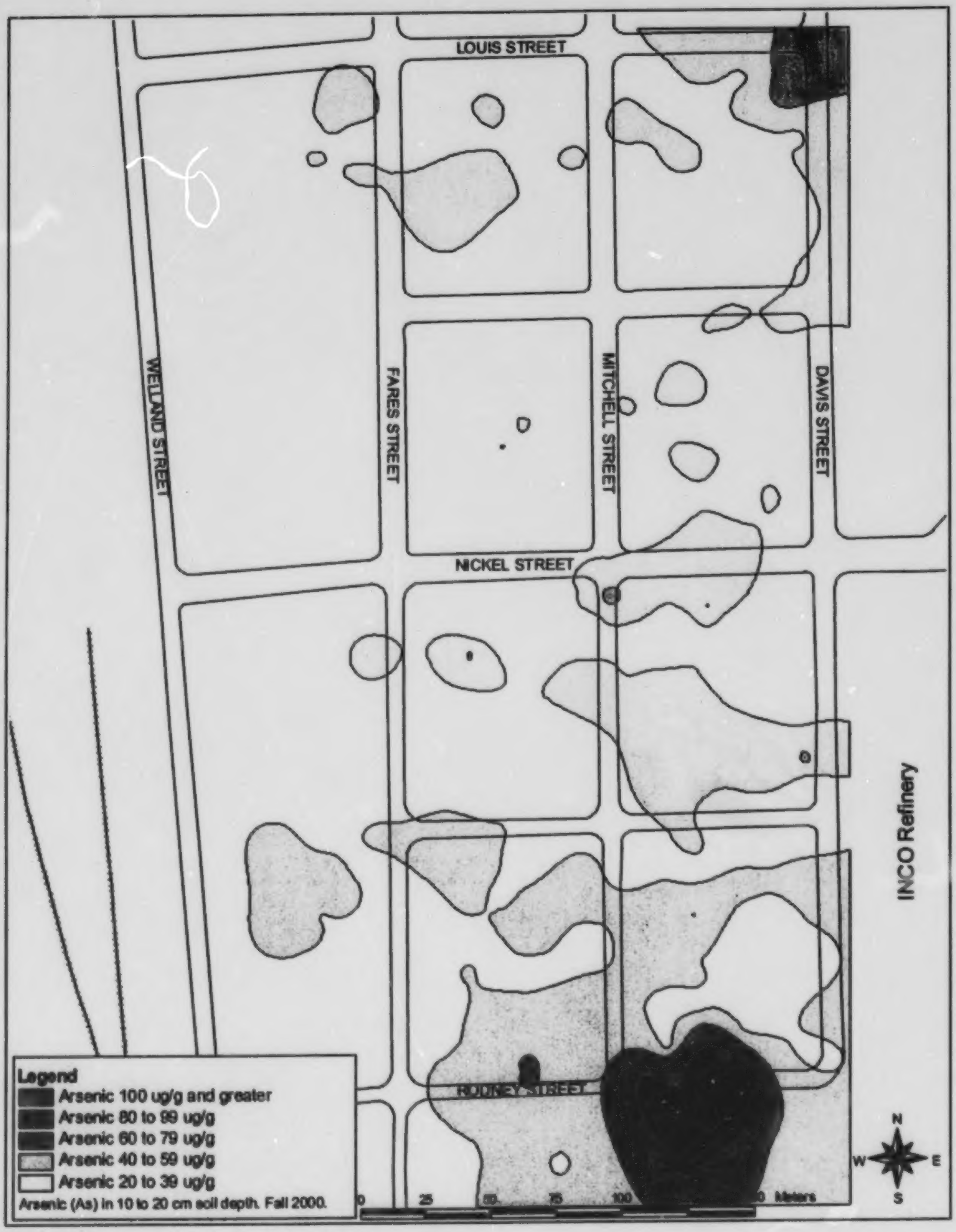
WELLAND STREET
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RO
INCO Refinery
Legend
Arsenic 80 ug/g and greater
Arsenic 60 to 79 ug/g
Arsenic 40 to 59 ug/g
Arsenic 20 to 39 ug/g
Arsenic (As) in 5 to 10 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
W
E
S

Map A5: Arsenic in 5 to 10 cm soil depth.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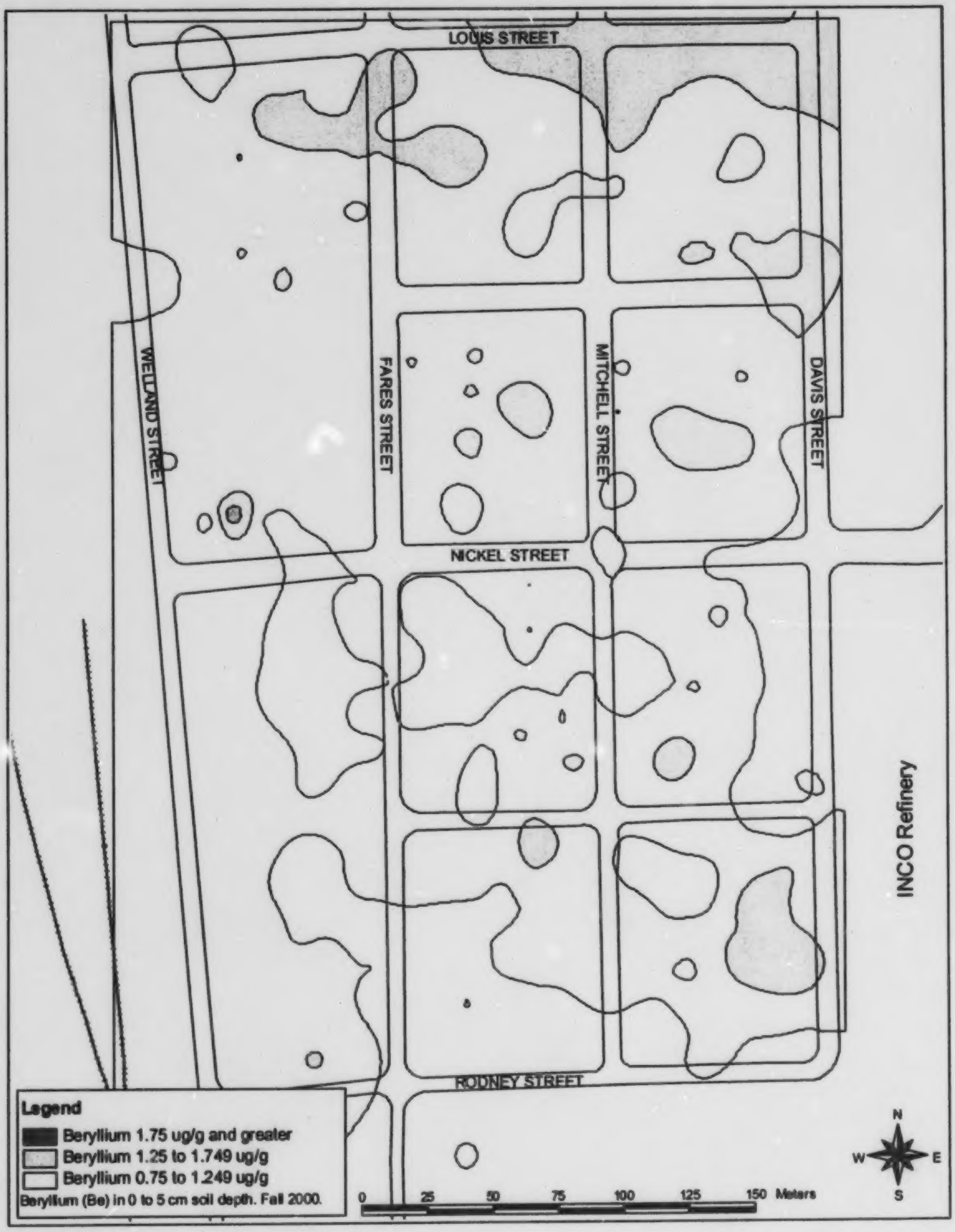
WELLAND STREET
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
N
W
E
S
0
25
50
75
100
Meters
Legend
Arsenic 100 ug/g and greater
Arsenic 80 to 99 ug/g
Arsenic 60 to 79 ug/g
Arsenic 40 to 59 ug/g
Arsenic 20 to 39 ug/g
Arsenic (As) in 10 to 20 cm soil depth. Fall 2000.

Map A6: Arsenic in 10 to 20 cm soil depth.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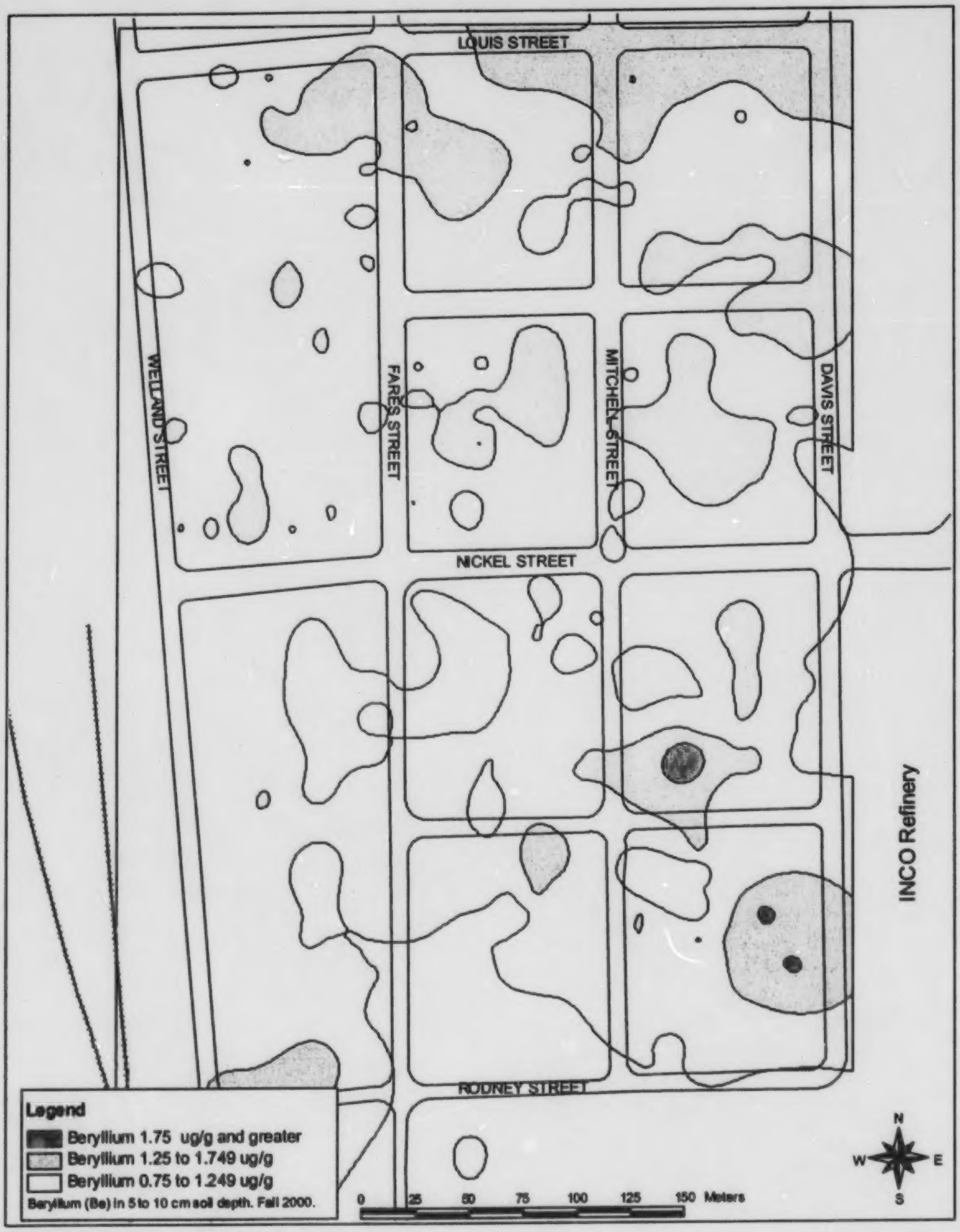
WELLAND STREET
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Beryllium 1.75 ug/g and greater
Beryllium 1.25 to 1.749 ug/g
Beryllium 0.75 to 1.249 ug/g
Beryllium (Be) in 0 to 5 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
W
E
S

Map A7: Beryllium in 0 to 5 cm soil depth.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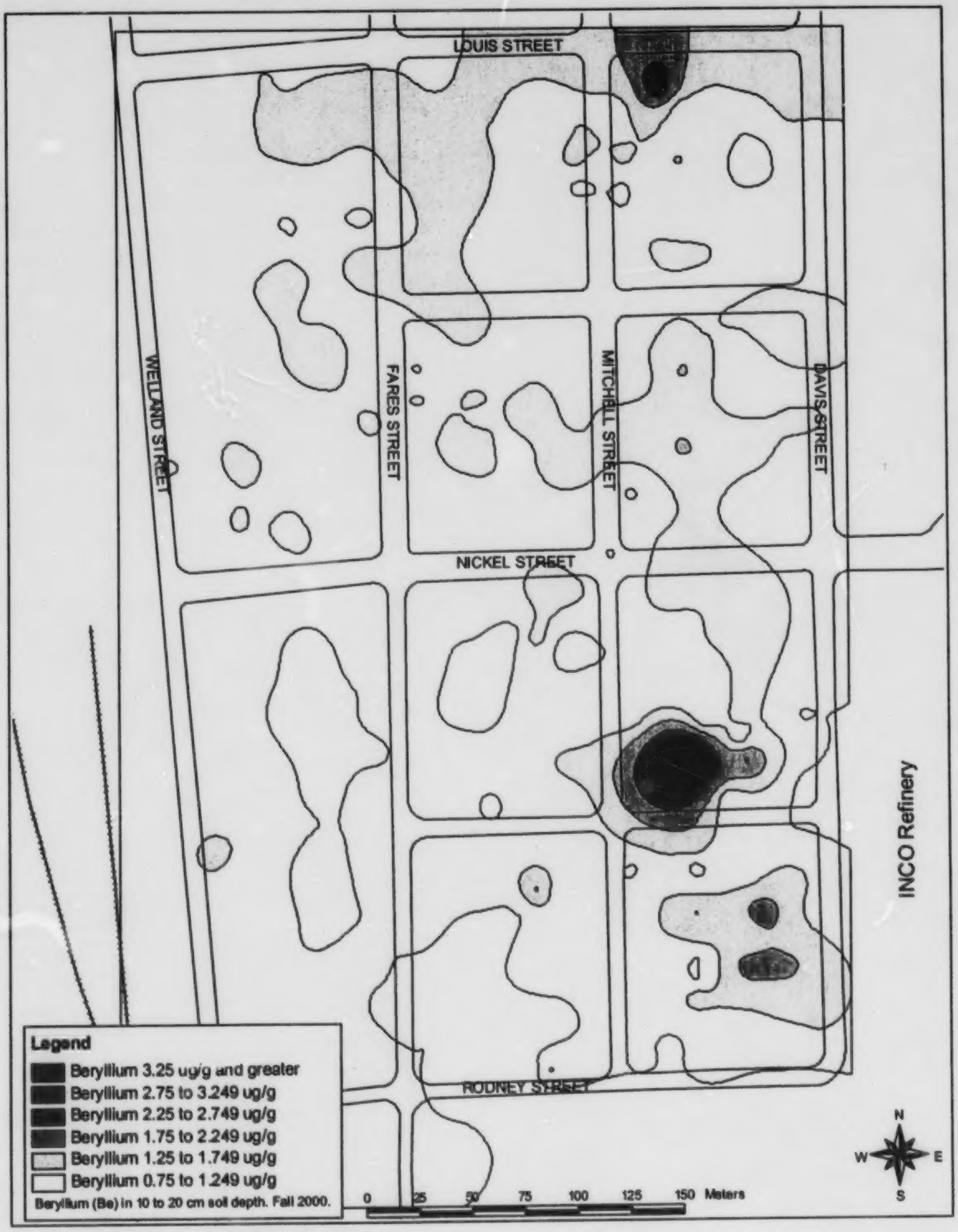
WELLAND STREET
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Beryllium 1.75 ug/g and greater
Beryllium 1.25 to 1.749 ug/g
Beryllium 0.75 to 1.249 ug/g
Beryllium (Be) in 5 to 10 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
W
E
S

Map A8: Beryllium in 5 to 10 cm depth.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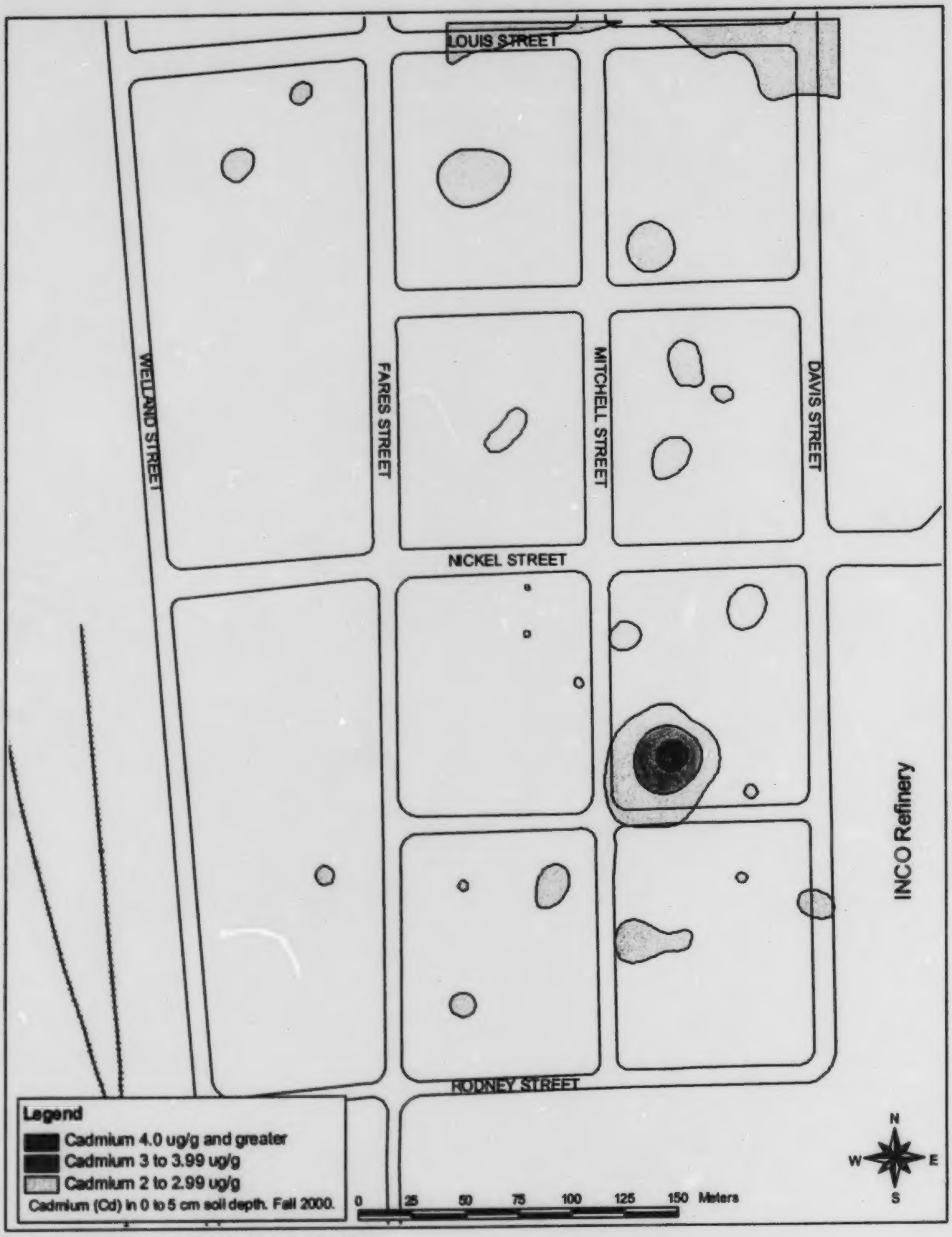
WELLAND STREET
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Beryllium 3.25 ug/g and greater
Beryllium 2.75 to 3.249 ug/g
Beryllium 2.25 to 2.749 ug/g
Beryllium 1.75 to 2.249 ug/g
Beryllium 1.25 to 1.749 ug/g
Beryllium 0.75 to 1.249 ug/g
Beryllium (Be) in 10 to 20 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
W
E
S

Map A9: Beryllium in 10 to 20 soil depth.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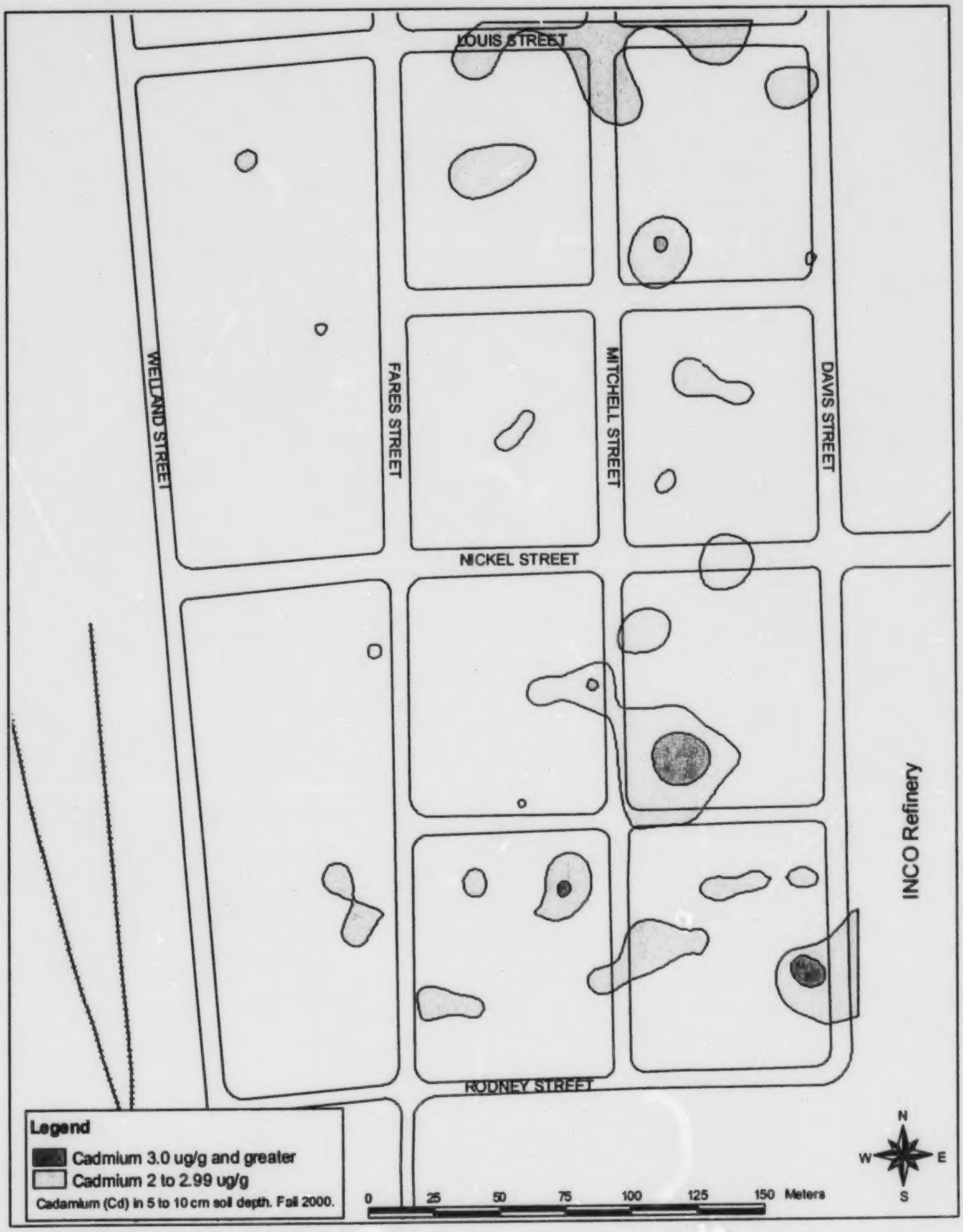
WELLAND STREET
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Cadmium 4.0 ug/g and greater
Cadmium 3 to 3.99 ug/g
Cadmium 2 to 2.99 ug/g
Cadmium (Cd) in 0 to 5 cm soil depth. Fall 2000.
0
25
50
75
100
125
150
Meters
N
E
S
W

Map A10: Cadmium in 0 to 5 cm soil depth.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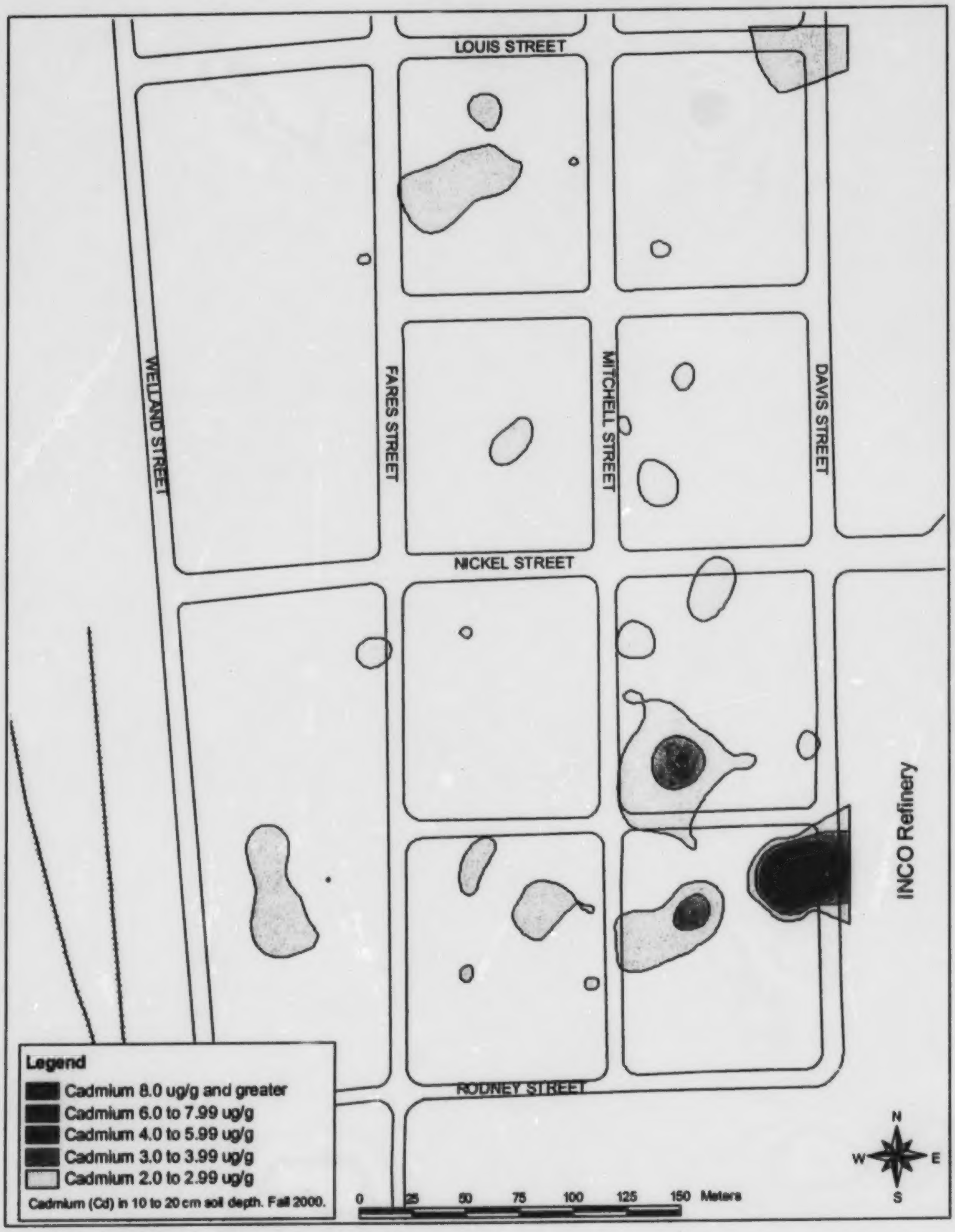
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Cadmium 3.0 ug/g and greater
Cadmium 2 to 2.99 ug/g
Cadamium (Cd) in 5 to 10 cm soil depth. Fall 2000.
0
25
50
75
100
125
150
Meters
N
W
E
S

Map A11: Cadmium in 5 to 10 cm soil depth.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FARES STREET
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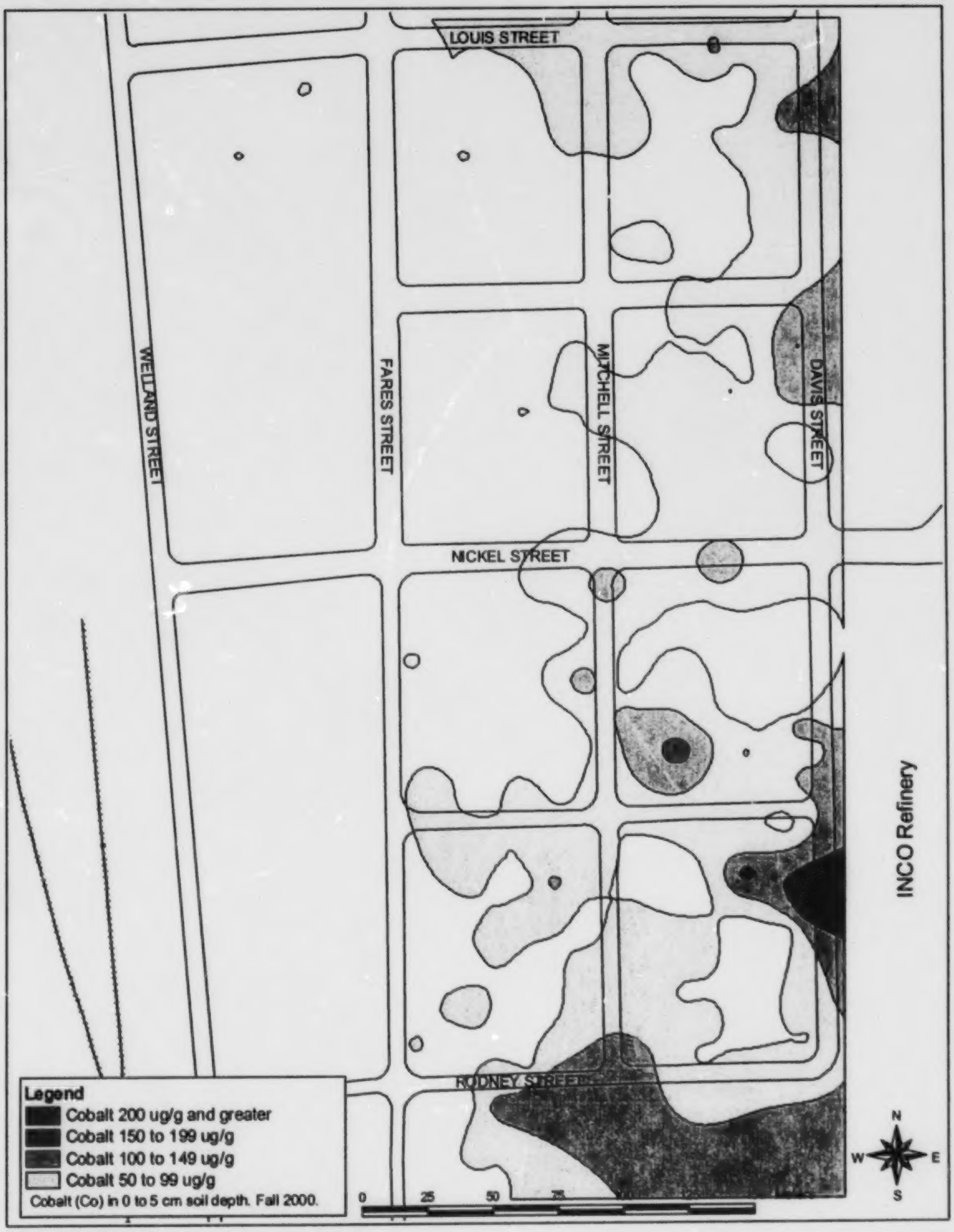
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Cadmium 8.0 ug/g and greater
Cadmium 6.0 to 7.99 ug/g
Cadmium 4.0 to 5.99 ug/g
Cadmium 3.0 to 3.99 ug/g
Cadmium 2.0 to 2.99 ug/g
Cadmium (Cd) in 10 to 20 cm soil depth. Fall 2000.
0
25
50
75
100
125
150
Meters
N
W
E
S

Map A12: Cadmium in 10 to 20 cm soil depth.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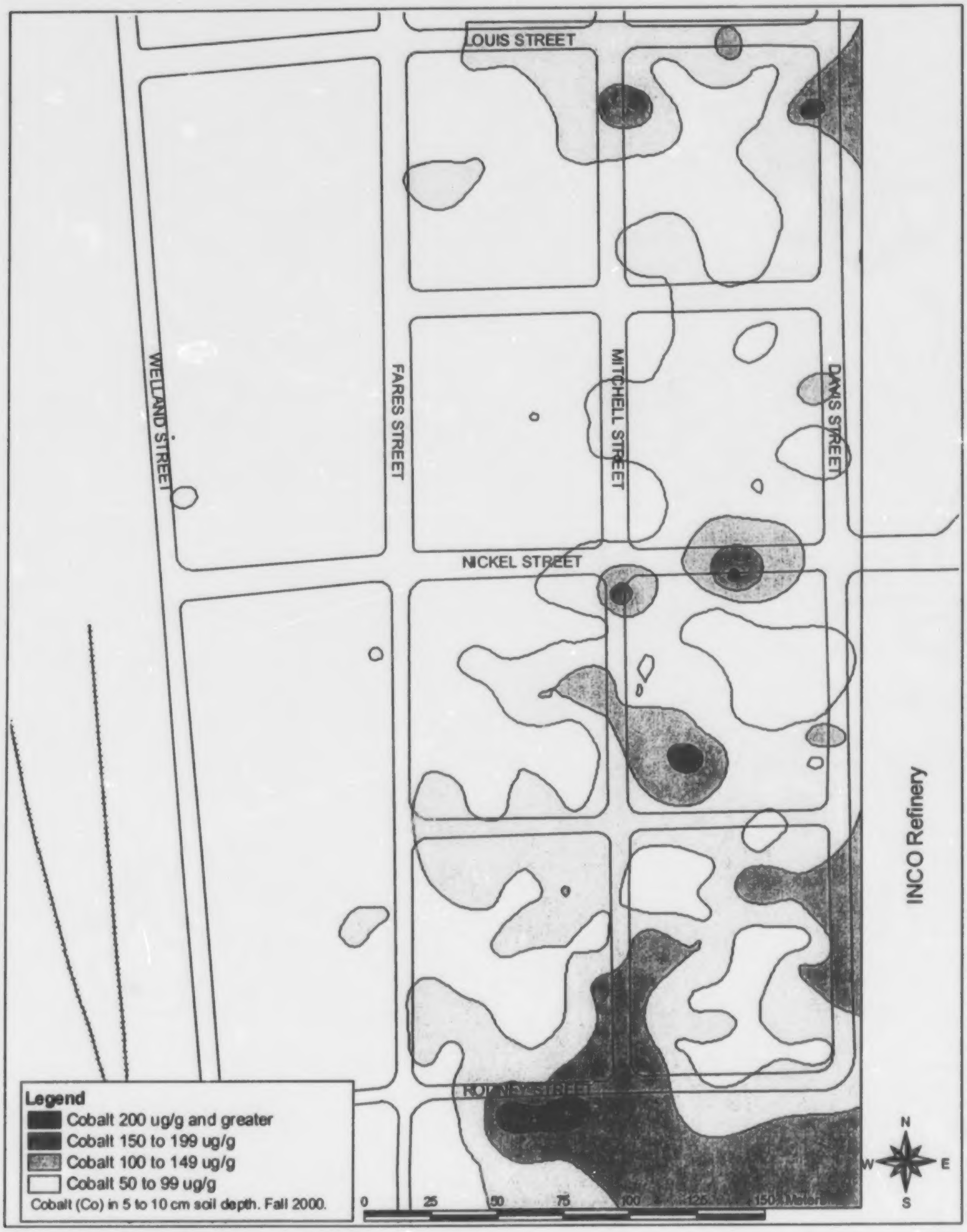
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Cobalt 200 ug/g and greater
Cobalt 150 to 199 ug/g
Cobalt 100 to 149 ug/g
Cobalt 50 to 99 ug/g
Cobalt (Co) in 0 to 5 cm soil depth. Fall 2000.
0
25
50
75
N
W
E
S

Map A13: Cobalt in 0 to 5 cm soil depth.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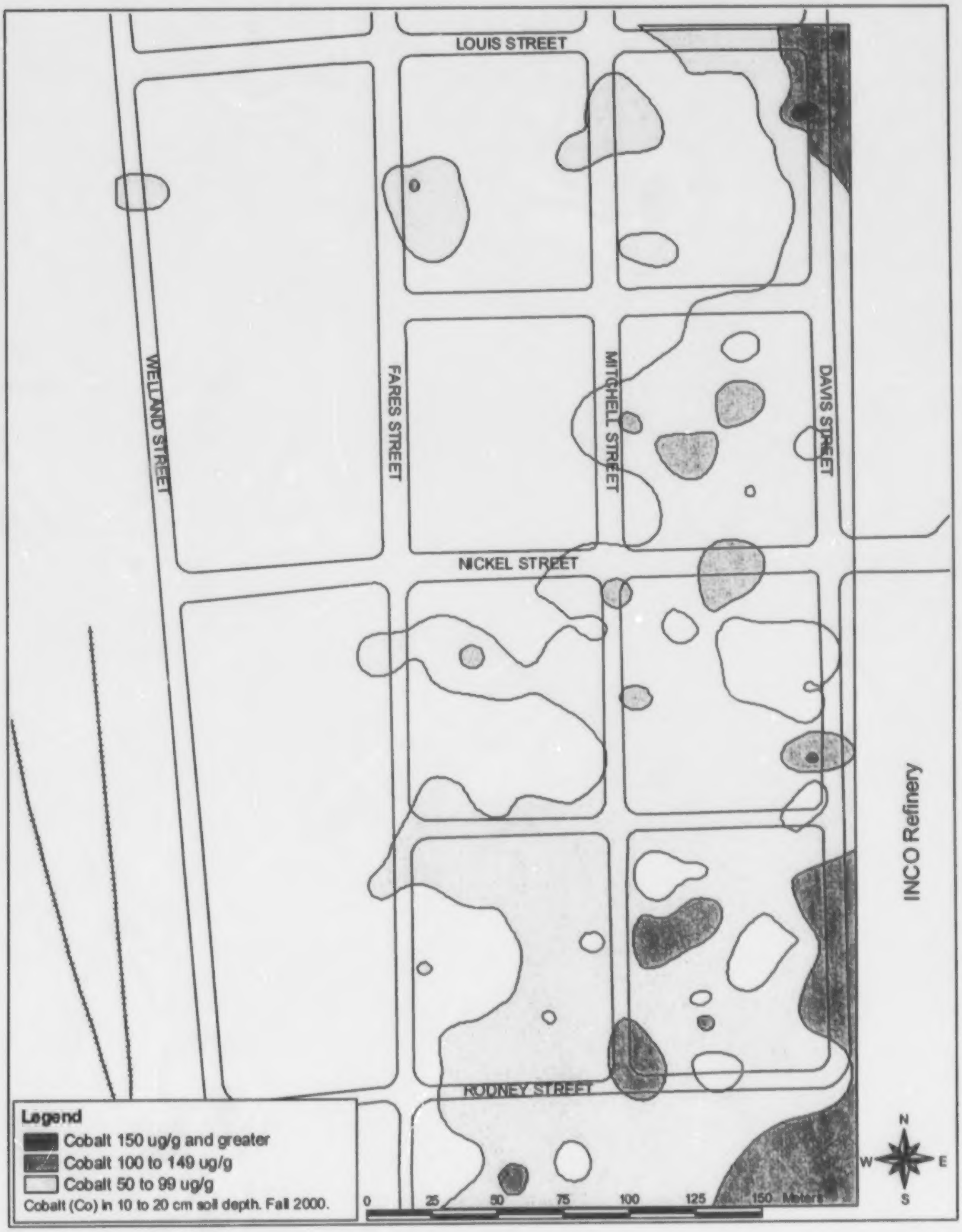
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Cobalt 200 ug/g and greater
Cobalt 150 to 199 ug/g
Cobalt 100 to 149 ug/g
Cobalt 50 to 99 ug/g
Cobalt (Co) in 5 to 10 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
W
E
S

Map A14: Cobalt in 5 to 10 cm soil depth.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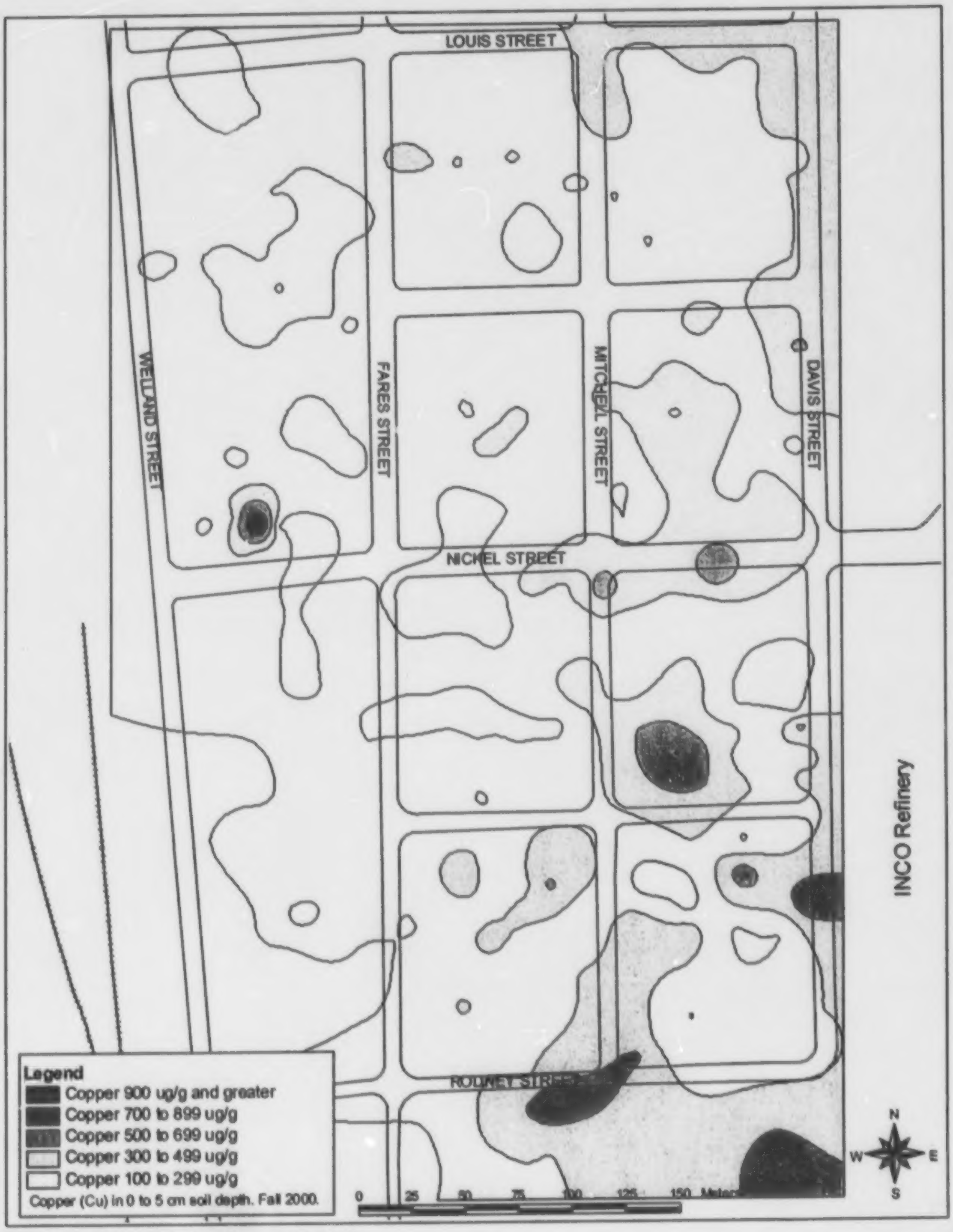
Legend
Cobalt 150 ug/g and greater
Cobalt 100 to 149 ug/g
Cobalt 50 to 99 ug/g
Cobalt (Co) in 10 to 20 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
W
E
S

Map A15: Cobalt in 10 to 20 cm soil depth.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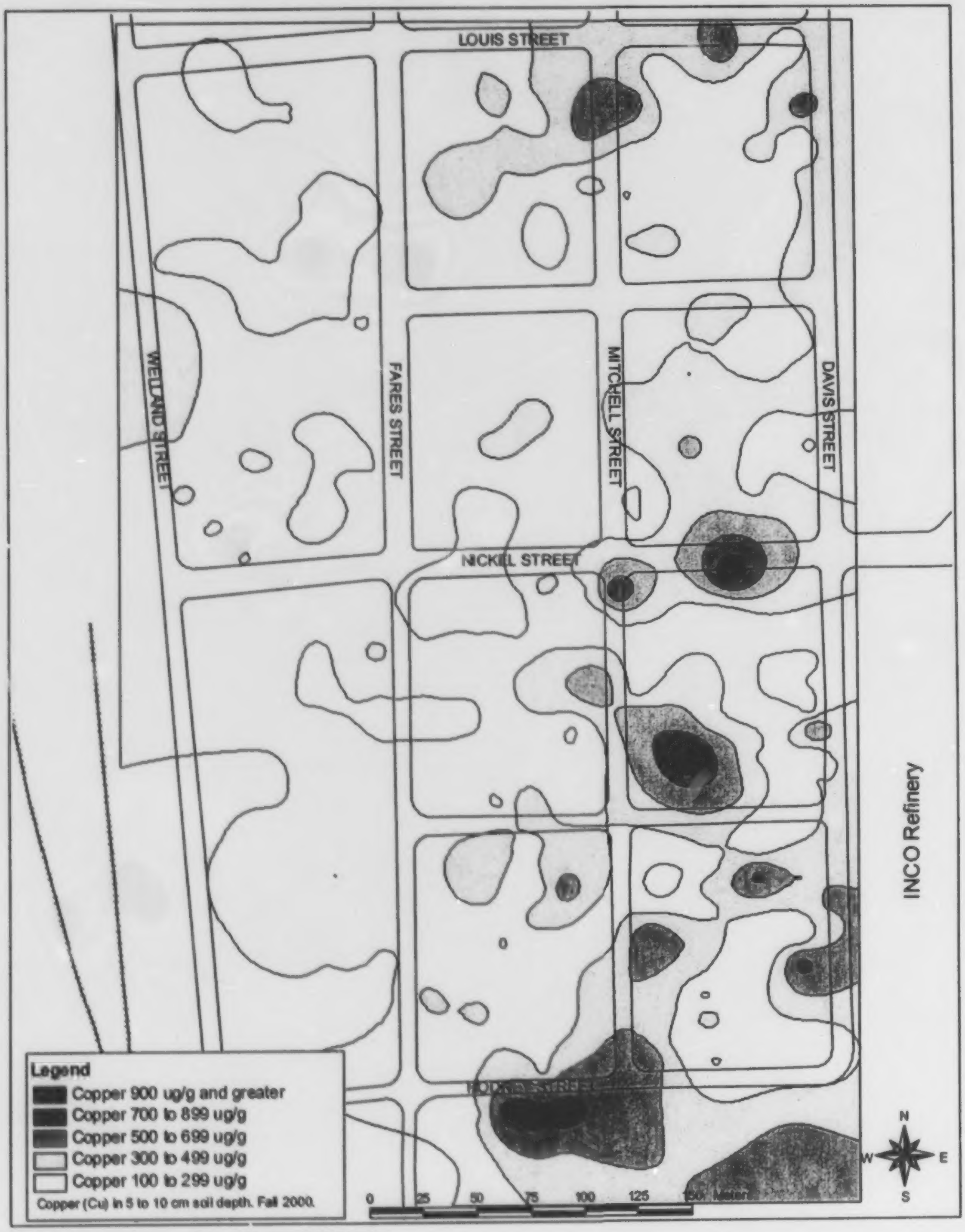
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Copper 900 ug/g and greater
Copper 700 to 899 ug/g
Copper 500 to 699 ug/g
Copper 300 to 499 ug/g
Copper 100 to 299 ug/g
Copper (Cu) in 0 to 5 cm soil depth. Fall 2000.
0
25
50
75
100
125
150
Meters
N
W
E
S

Map A16: Copper in 0 to 5 cm soil depth.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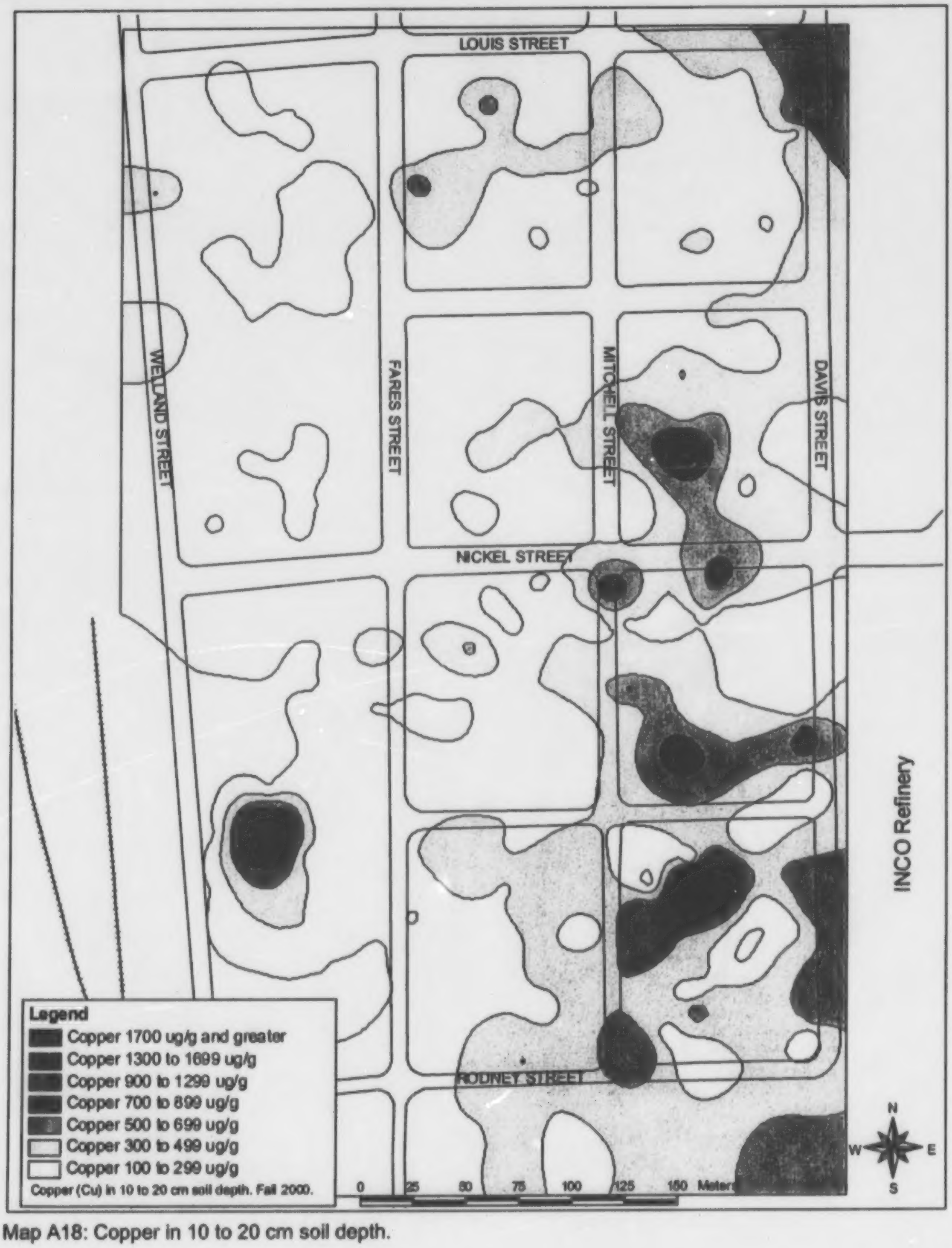
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Copper 900 ug/g and greater
Copper 700 to 899 ug/g
Copper 500 to 699 ug/g
Copper 300 to 499 ug/g
Copper 100 to 299 ug/g
Copper (Cu) in 5 to 10 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meter
N
W
E
S

Map A17: Copper in 5 to 10 cm soil depth.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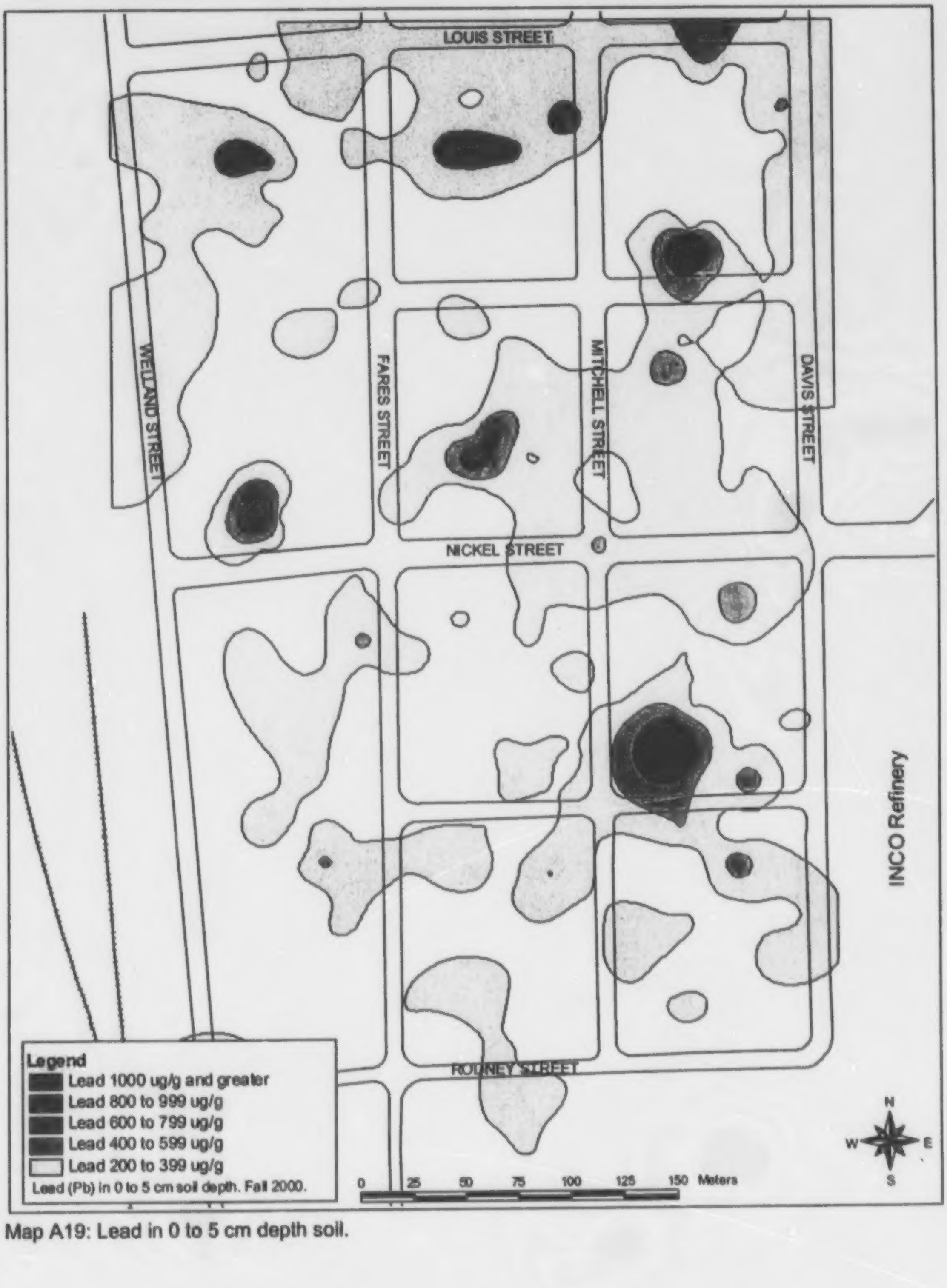
WELLAND STREET
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Copper 1700 ug/g and greater
Copper 1300 to 1699 ug/g
Copper 900 to 1299 ug/g
Copper 700 to 899 ug/g
Copper 500 to 699 ug/g
Copper 300 to 499 ug/g
Copper 100 to 299 ug/g
Copper (Cu) in 10 to 20 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
W
E
S

Map A18: Copper in 10 to 20 cm soil depth.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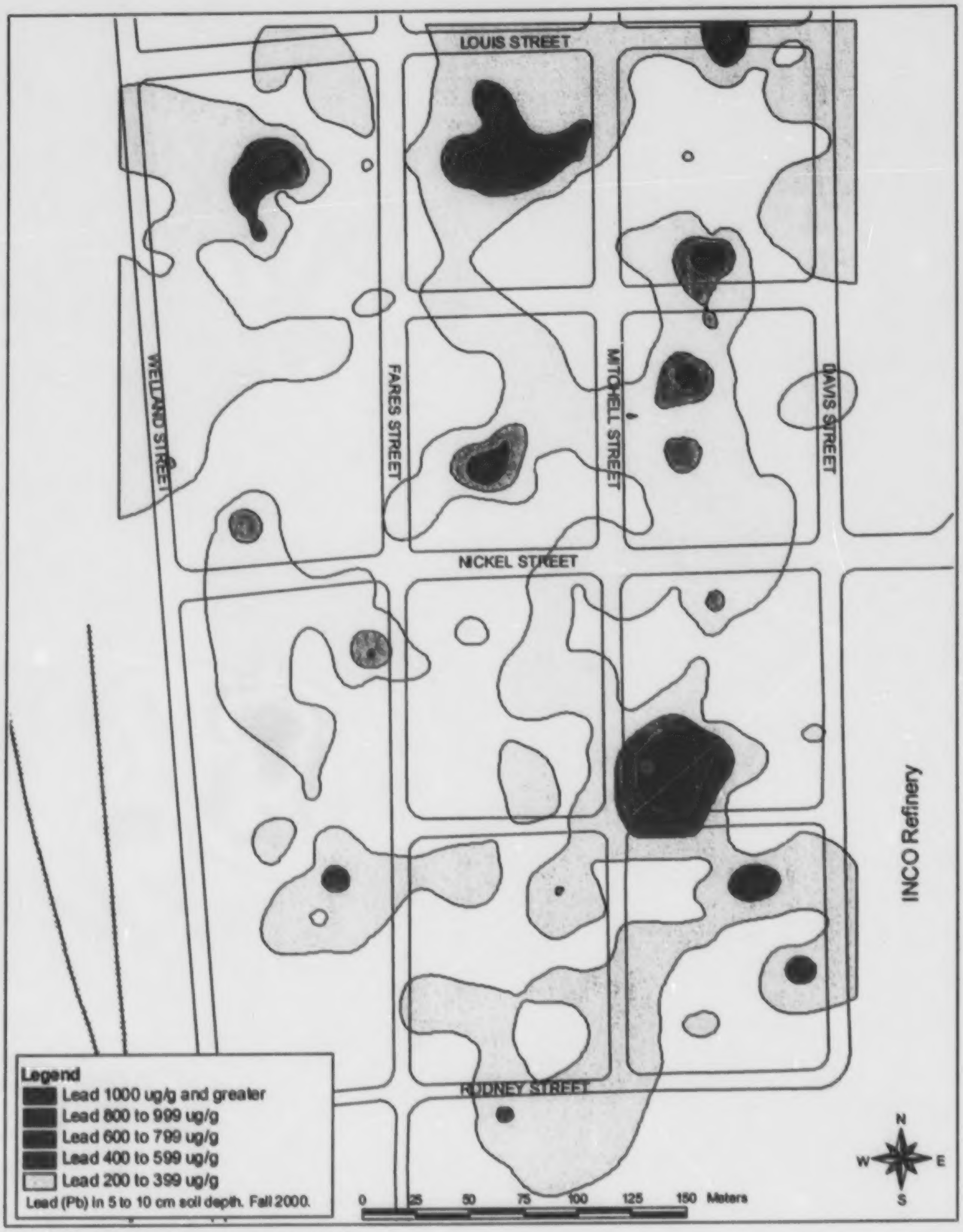
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Lead 1000 ug/g and greater
Lead 800 to 999 ug/g
Lead 600 to 799 ug/g
Lead 400 to 599 ug/g
Lead 200 to 399 ug/g
Lead (Pb) in 0 to 5 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
W
E
S

Map A19: Lead in 0 to 5 cm depth soil.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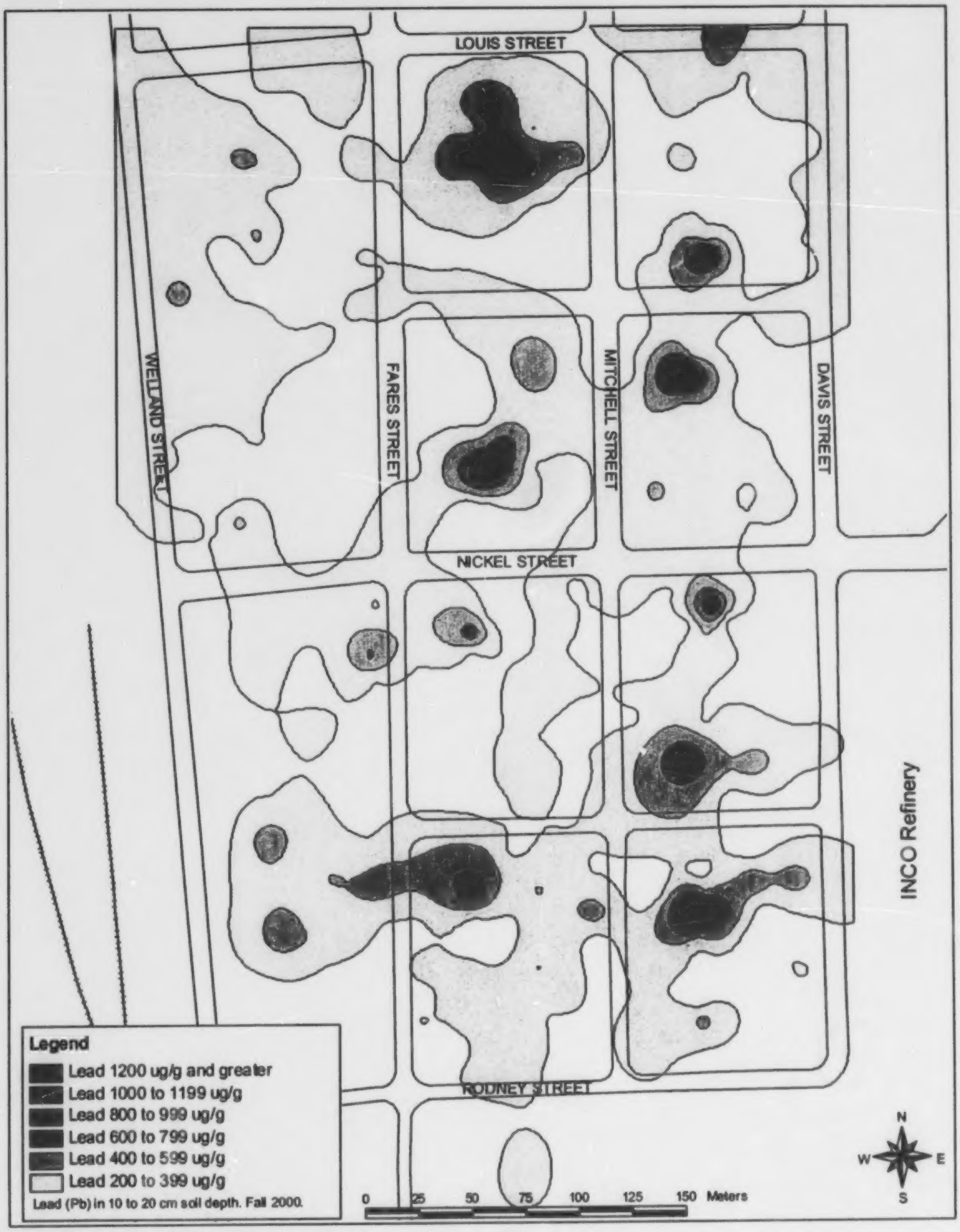
RODNEY STREET
INCO Refinery
Legend
Lead 1000 ug/g and greater
Lead 800 to 999 ug/g
Lead 600 to 799 ug/g
Lead 400 to 599 ug/g
Lead 200 to 399 ug/g
Lead (Pb) in 5 to 10 cm soil depth. Fall 2000.
0
25
50
75
100
125
150
Meters
N
S
E
W

Map A20: Lead in 5 to 10 cm soil depth.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MITCHELL STREET
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NICKEL STREET
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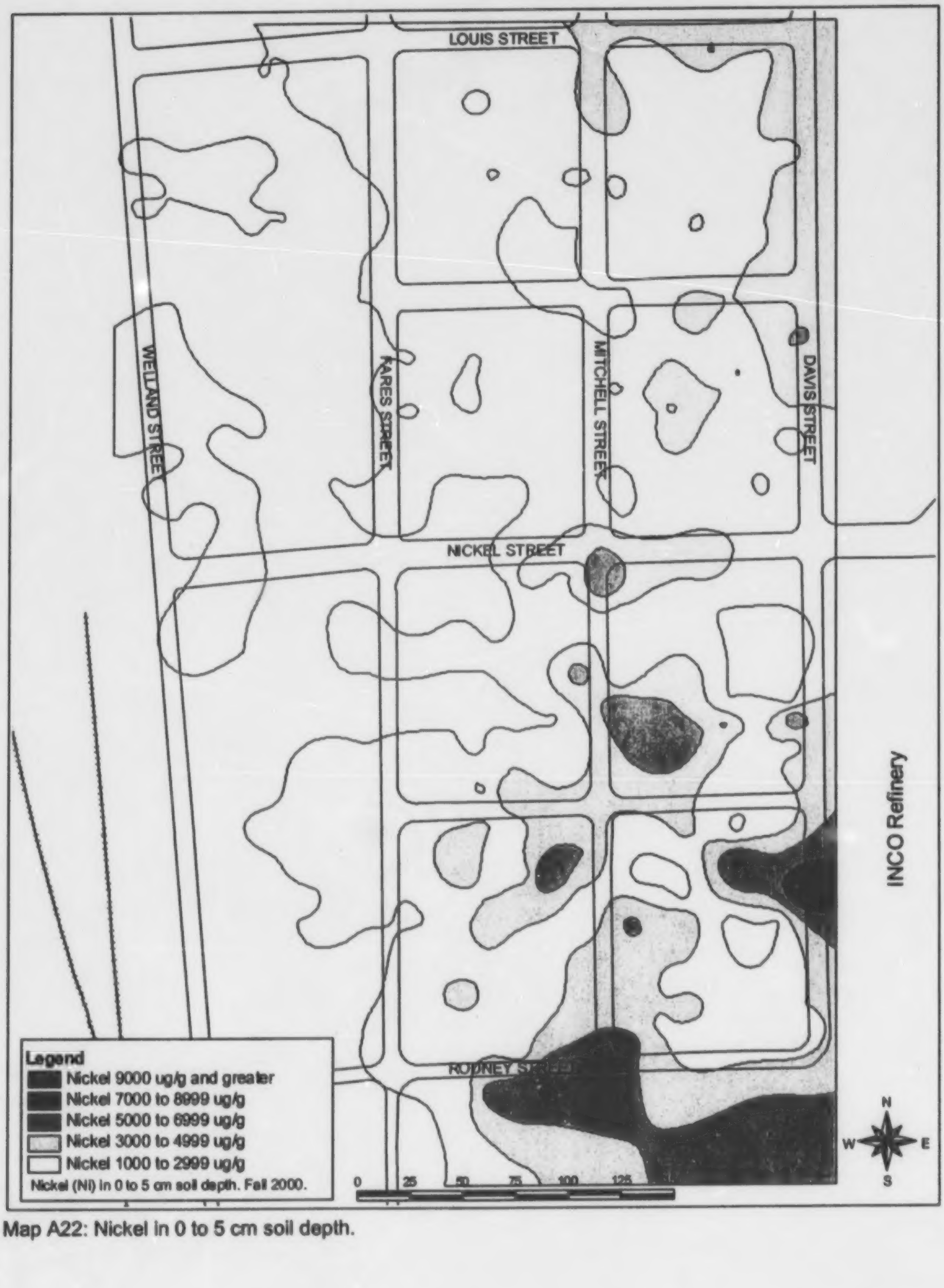
INCO Refinery
Legend
Lead 1200 ug/g and greater
Lead 1000 to 1199 ug/g
Lead 800 to 999 ug/g
Lead 600 to 799 ug/g
Lead 400 to 599 ug/g
Lead 200 to 399 ug/g
Lead (Pb) in 10 to 20 cm soil depth. Fall 2000.
0
25
50
75
100
125
150
Meters
N
W
E
S

Map A21: Lead in 10 to 20 cm soil depth.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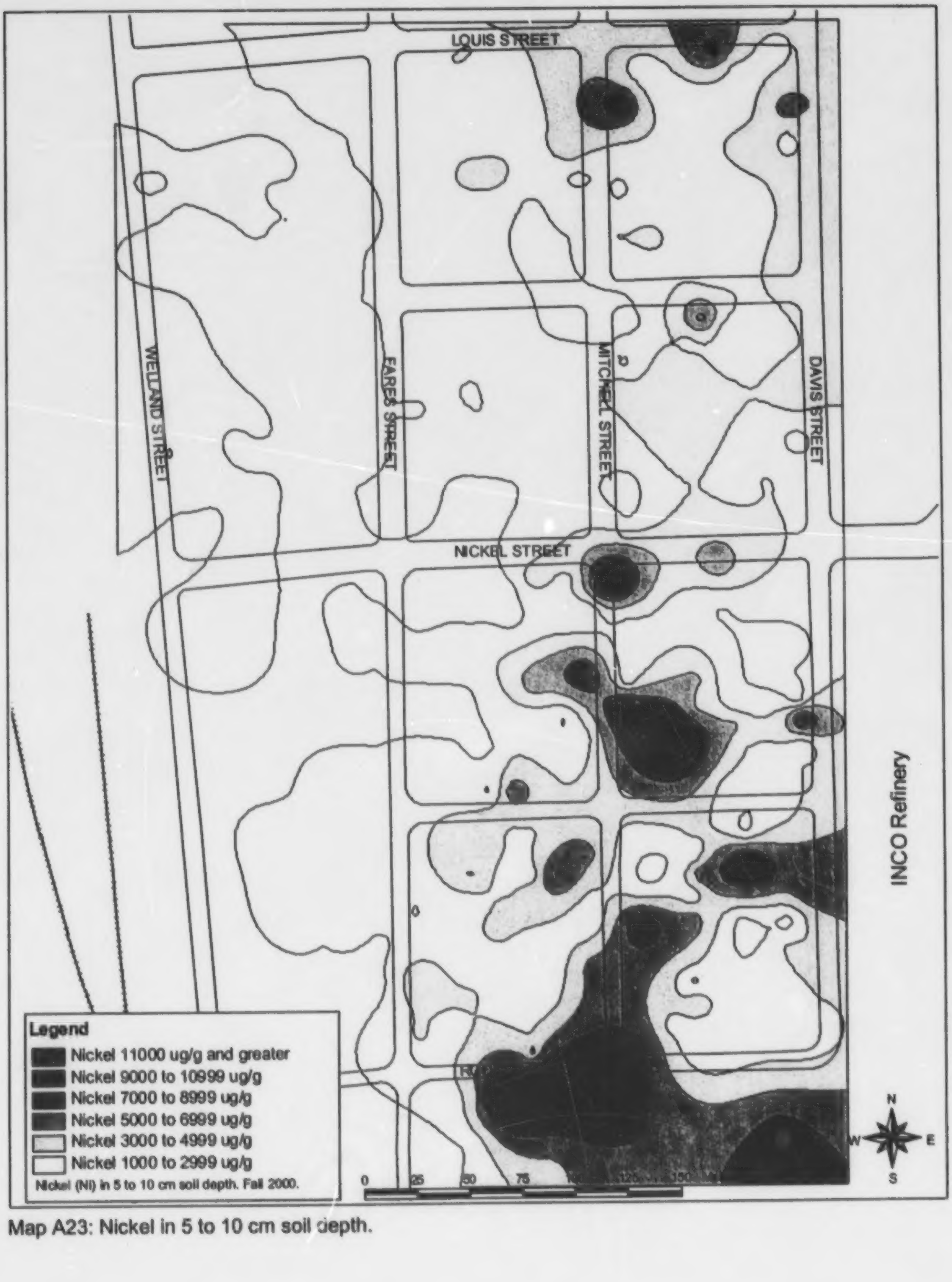
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Nickel 9000 ug/g and greater
Nickel 7000 to 8999 ug/g
Nickel 5000 to 6999 ug/g
Nickel 3000 to 4999 ug/g
Nickel 1000 to 2999 ug/g
Nickel (Ni) in 0 to 5 cm soil depth. Fall 2000.
0
25
50
75
100
125
N
W
E
S

Map A22: Nickel in 0 to 5 cm soil depth.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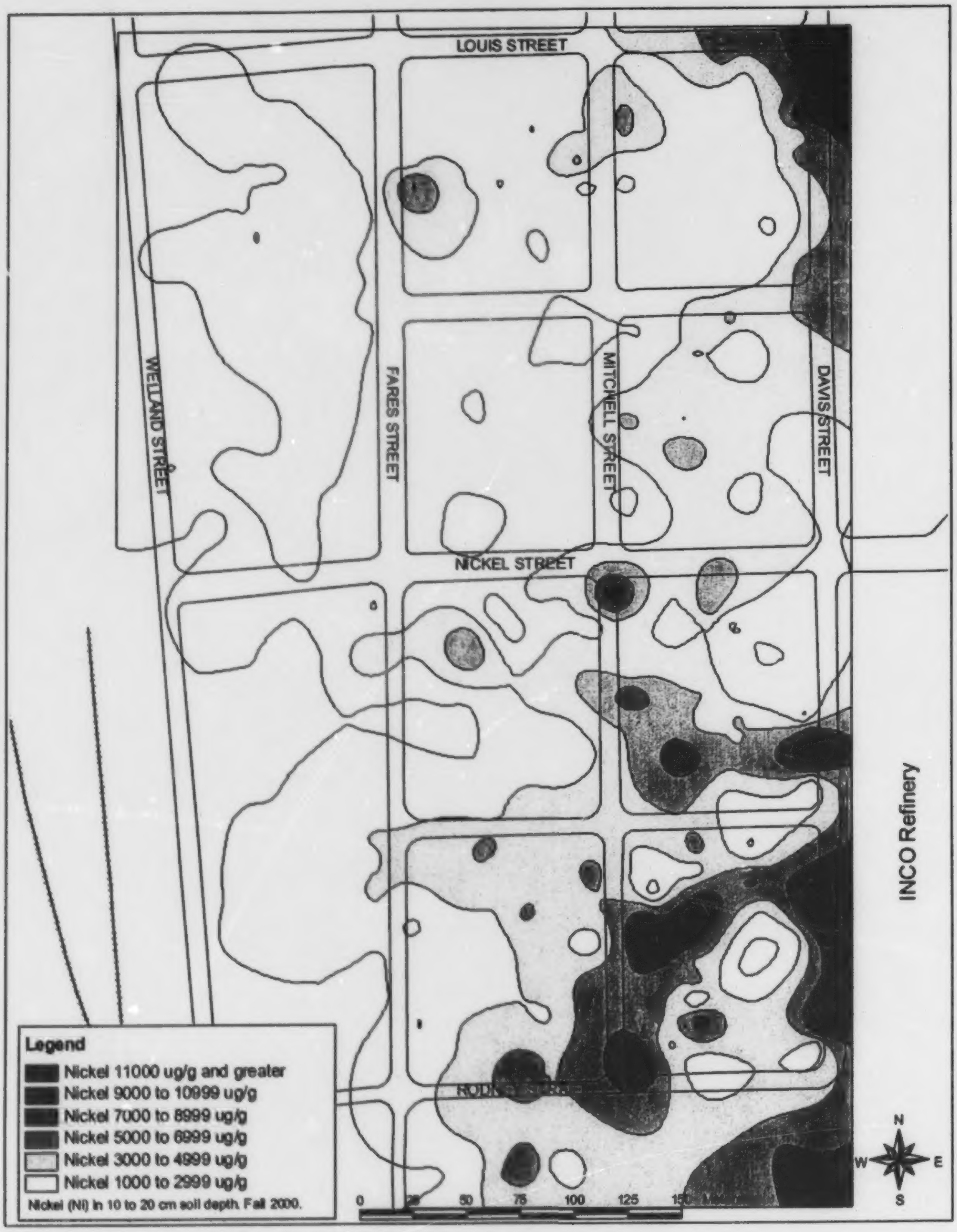
NICKEL STREET
RO
INCO Refinery
Legend
Nickel 11000 ug/g and greater
Nickel 9000 to 10999 ug/g
Nickel 7000 to 8999 ug/g
Nickel 5000 to 6999 ug/g
Nickel 3000 to 4999 ug/g
Nickel 1000 to 2999 ug/g
Nickel (Ni) in 5 to 10 cm soil depth. Fall 2000.
0
25
50
75
100
125
150
N
W
E
S

Map A23: Nickel in 5 to 10 cm soil depth.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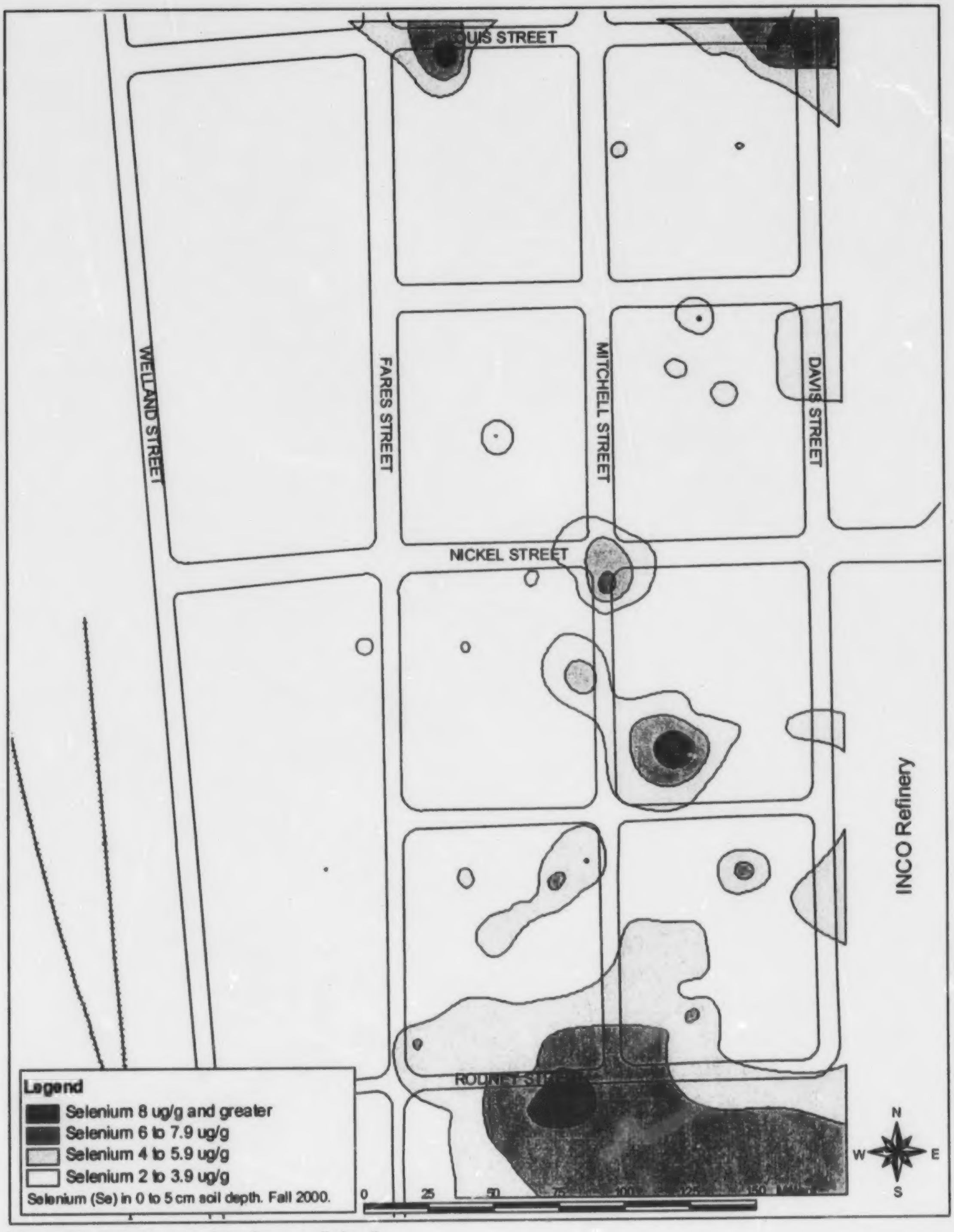
INCO Refinery
Legend
Nickel 11000 ug/g and greater
Nickel 9000 to 10999 ug/g
Nickel 7000 to 8999 ug/g
Nickel 5000 to 6999 ug/g
Nickel 3000 to 4999 ug/g
Nickel 1000 to 2999 ug/g
Nickel (Ni) in 10 to 20 cm soil depth. Fall 2000.
0
25
50
75
100
125
150
Meters
N
W
E
S

Map A24: Nickel in 10 to 20 cm soil depth.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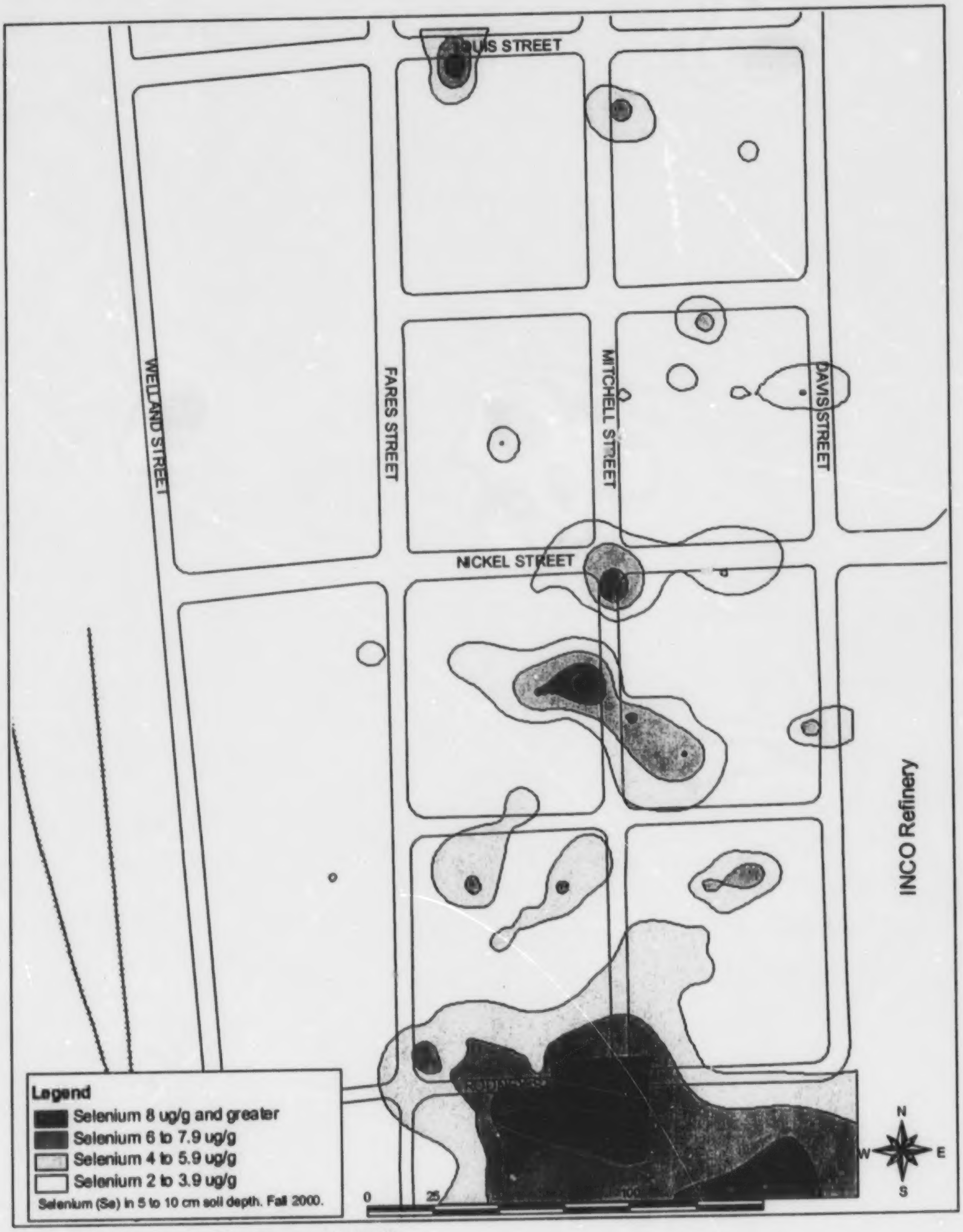
DAVIS STREET
NICKEL STREET
RODNEY STREET
INCO Refinery
Legend
Selenium 8 ug/g and greater
Selenium 6 to 7.9 ug/g
Selenium 4 to 5.9 ug/g
Selenium 2 to 3.9 ug/g
Selenium (Se) in 0 to 5 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
W
E
S

Map A25: Selenium in 0 to 5 cm soil depth.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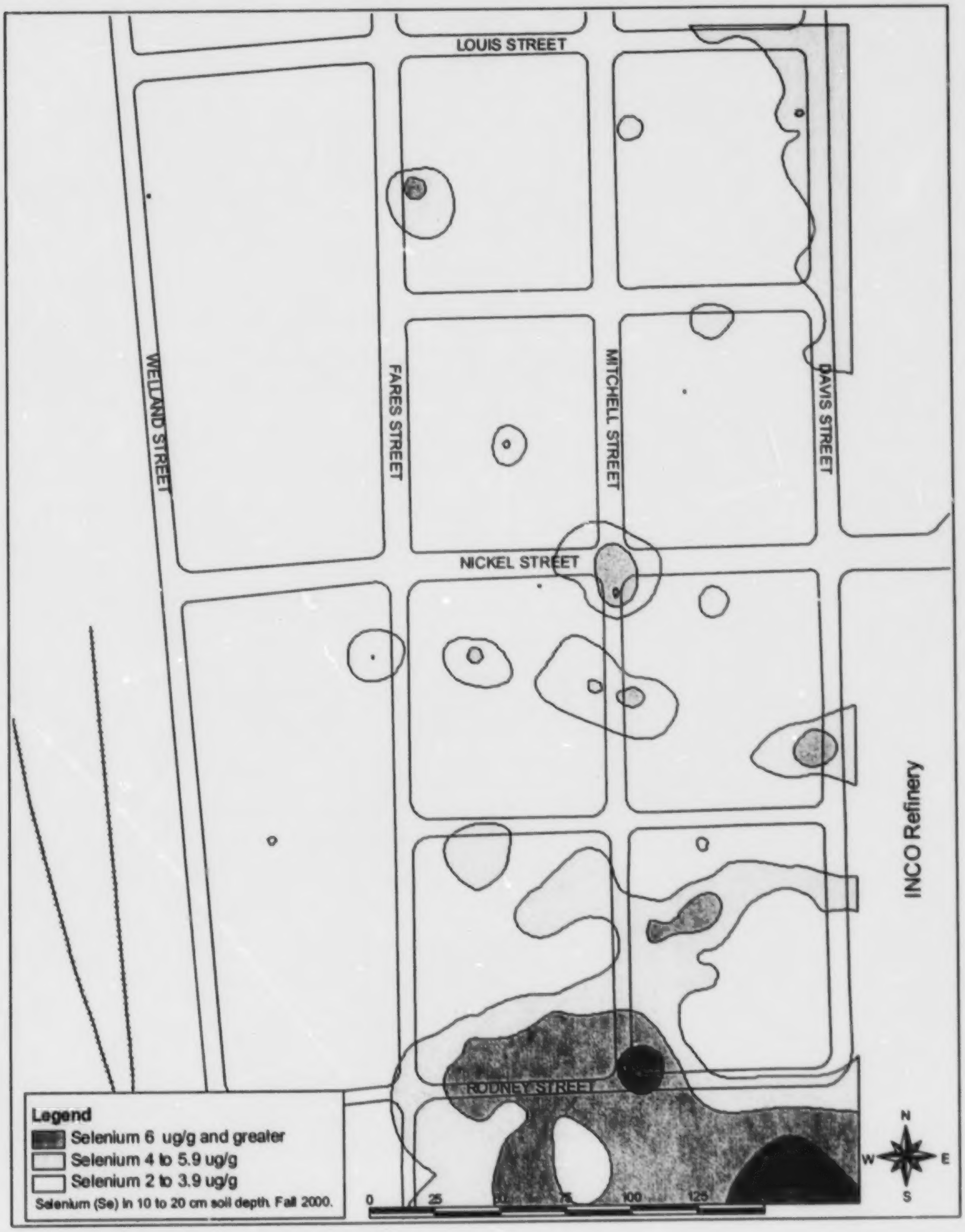
DAVIS STREET
NICKEL STREET
RODNEY ST
INCO Refinery
Legend
Selenium 8 ug/g and greater
Selenium 6 to 7.9 ug/g
Selenium 4 to 5.9 ug/g
Selenium 2 to 3.9 ug/g
Selenium (Se) in 5 to 10 cm soil depth. Fall 2000.
0
25
100
N
E
S
W

Map A26: Selenium in 5 to 10 cm soil depth.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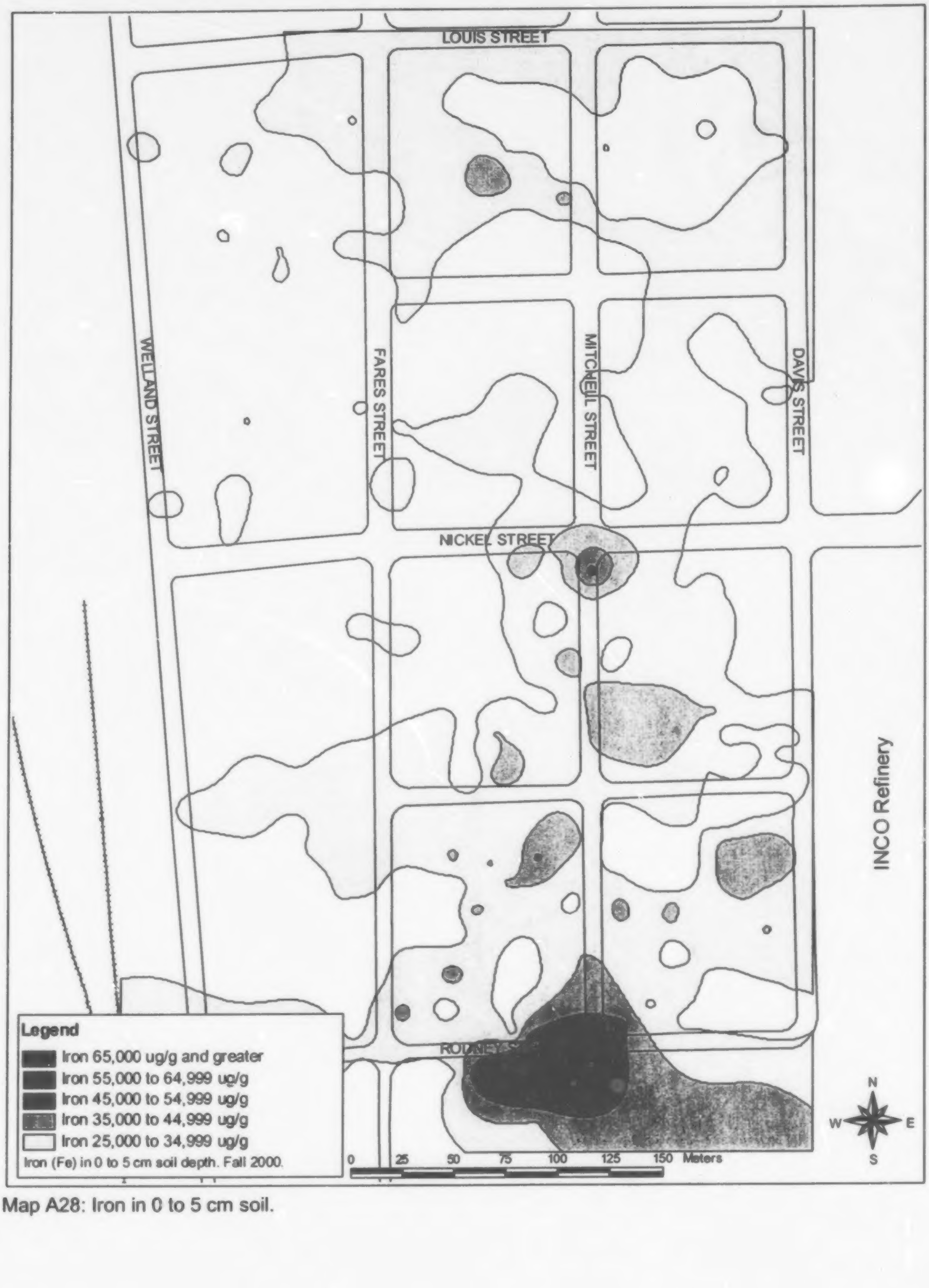
INCO Refinery
Legend
Selenium 6 ug/g and greater
Selenium 4 to 5.9 ug/g
Selenium 2 to 3.9 ug/g
Selenium (Se) in 10 to 20 cm soil depth. Fall 2000.
0
25
50
75
100
125
N
W
E
S

Map A27: Selenium in 10 to 20 cm soil depth.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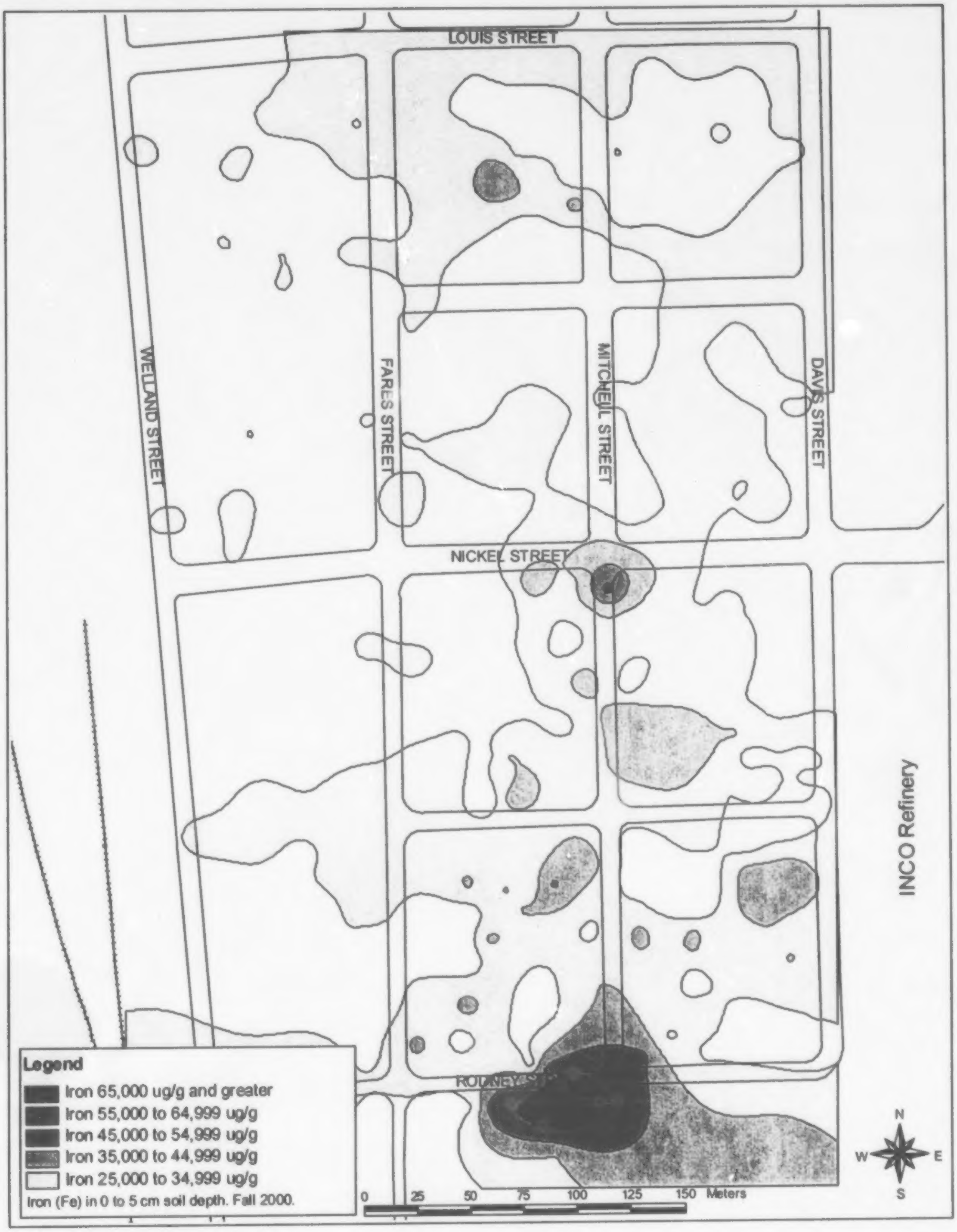
FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
RODNEY ST
INCO Refinery
Legend
Iron 65,000 ug/g and greater
Iron 55,000 to 64,999 ug/g
Iron 45,000 to 54,999 ug/g
Iron 35,000 to 44,999 ug/g
Iron 25,000 to 34,999 ug/g
Iron (Fe) in 0 to 5 cm soil depth. Fall 2000.
0 25 50 75 100 125 150 Meters
N
W
E
S

Map A28: Iron in 0 to 5 cm soil.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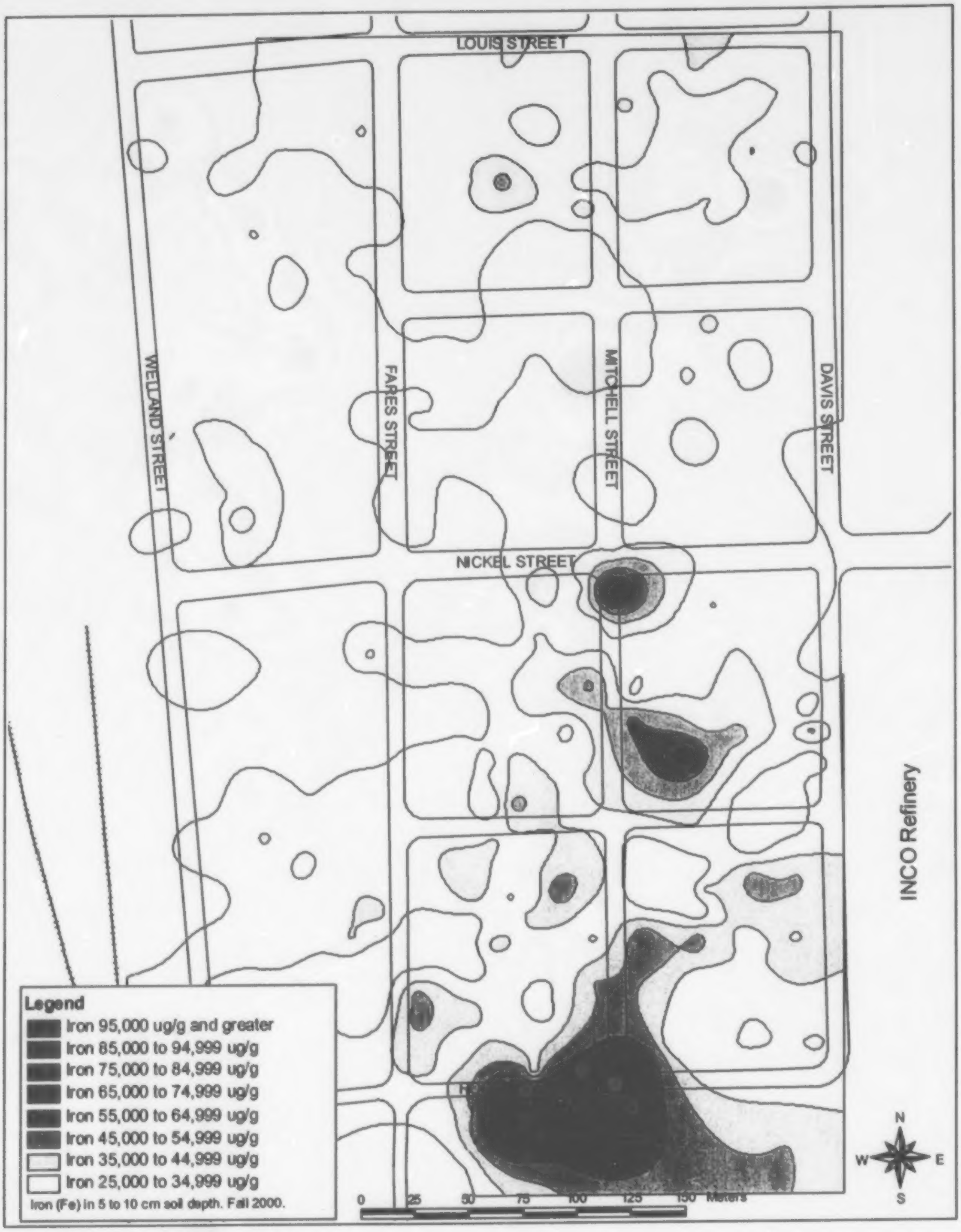
DAVIS STREET
NICKEL STREET
RODNEY ST
INCO Refinery
Legend
Iron 65,000 ug/g and greater
Iron 55,000 to 64,999 ug/g
Iron 45,000 to 54,999 ug/g
Iron 35,000 to 44,999 ug/g
Iron 25,000 to 34,999 ug/g
Iron (Fe) in 0 to 5 cm soil depth. Fall 2000.
0
25
50
75
100
125
150 Meters
N
E
S
W

Map A29: Iron in 5 to 10 cm soil.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FARES STREET
MITCHELL STREET
DAVIS STREET
NICKEL STREET
INCO Refinery
Legend
Iron 95,000 ug/g and greater
Iron 85,000 to 94,999 ug/g
Iron 75,000 to 84,999 ug/g
Iron 65,000 to 74,999 ug/g
Iron 55,000 to 64,999 ug/g
Iron 45,000 to 54,999 ug/g
Iron 35,000 to 44,999 ug/g
Iron 25,000 to 34,999 ug/g
Iron (Fe) in 5 to 10 cm soil depth. Fall 2000.
0 25 50 75 100 125 150 Meters
N
W
E
S

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# Part B

# Human Health Risk Assessment

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## 1.0 Introduction

This document is part of a combined Ontario Ministry of the Environment (MOE) Standards Development Branch soil investigation (Part A) and health-based risk assessment report (Part B). The health-based risk assessment is designed to answer community health concerns raised by the discovery of elevated levels of nickel and other metals below the normal surface soil sampling depth (0 - 5 cm) on a Rodney Street property in June 2000. The soil metal concentrations were higher than previously measured (Part A).

While this study is health-based, it is not a community health study. This health-based risk assessment is directed at assessing exposure to selected metals in Rodney Street properties to evaluate whether health-based exposure limits are exceeded and whether there is an exposure level (or soil concentration) that warrants further actions (including soil remediation) to reduce exposure to identified soil metal concentrations. The approach presented uses current soil levels based on the most recent soil monitoring information as shown in the accompanying soil investigation (Part A). Other exposure parameters include levels of metals in outdoor air, drinking water, supermarket food and home grown backyard vegetables and fruits. This information is used to estimate the exposure of Rodney Street community residents without taking measurements from people directly. By contrast, a health study can involve taking blood and urine samples (under medical supervision) to measure human exposures directly. Such procedures are not performed by the MOE. It should be noted that two health studies are ongoing in the Port Colborne area.

For historical reasons and the proximity of the Inco metal refinery, the primary focus of the investigation was directed at the widespread and elevated levels of nickel in the community. Initially this study was targeted at performing a detailed human health risk assessment (HHRA) for this metal. However, as information on other metals became available, a need to assess the potential for health risks due to these other metals was indicated, and a detailed HHRA for each of these other metals was performed. The other metals were initially selected for further study on the basis that their soil concentrations exceeded the residential soil quality criteria (*Table A*) of the Ministry's Guideline for Use at Contaminated Sites in Ontario (MOEE, 1997). Exceedance of the *Table A* guidelines does not necessarily imply that exposure constitutes an undue risk to health because the *Table A* guidelines are generic and several are based on ecotoxicological effects. Health based *Table A* guidelines incorporate an adequate margin of safety and are set well below any concentration where health effects might occur. Refer to Section 4.0 of Part A for a more detailed discussion of the derivation and application of these guidelines.

Because of the extensive knowledge of risks related to arsenic and lead in soil, particularly through similar and more detailed risk assessments and health studies in other Ontario towns and cities, a careful analysis comparing levels, conditions and risk in these other situations to levels and conditions in the Rodney Street community allowed meaningful insight into the question of possible increased risk. Additionally, for both lead and arsenic, a weight of evidence approach with consideration of various factors from the most recent scientific and regulatory literature including recent assessments conducted in other Ontario communities, are used to support derivation of appropriate intervention levels.

## 1.1 Purpose and Scope

A human health risk assessment of the elevated metal(s) concentrations found in the soil in the Rodney Street community of Port Colborne, Ontario was conducted by the Ontario Ministry of the Environment and released on March 30, 2001. On May 2nd, 2001, a letter was sent to the residents of the Rodney Street community advising them that the Ministry was reassessing its March 30th report. This reassessment was due to the discovery of a calculation error in one of the test methods used by the Ministry in establishing the intervention level. In addition, the Ministry received a number of comments with respect to the Ministry being either too stringent or not stringent enough in some of the values it used and the approach it took in developing the intervention level for nickel.

In response to these developments, the Ministry initiated new studies to verify the bioaccessibility of metals in Rodney Street community soils, and to obtain more information on the speciation of nickel in these soils. This new information and the comments received resulted in this revised version of the soil investigation and HHRA for Rodney Street community, and a revised soil intervention level of 8,000 ppm for nickel. The health risk assessment has undergone further peer review by an international panel of peer reviewers prior to public release (see Appendix 8).

MOE adopted a risk assessment framework to evaluate the environmental and human health risks of metals in Rodney Street community soils. The risk assessment paradigm which has dominated the regulatory decision making processes for the past two decades is the one promulgated in the 1983 US National Research Council (NRC) document, "Risk assessment in the federal government: Managing the process" (NRC, 1983a). This risk assessment paradigm and local variations on its theme has been adopted worldwide. As well as U.S. agencies, it is used by Canada and the Provinces, WHO (World Health Organization) and jurisdictions in most countries. Detailed methodologies for interpreting toxicological information and the various exposure pathways are extensive and are constantly being updated, as the science evolves.

The human health risk assessment makes use of environmental monitoring data and recent toxicological information to estimate exposures and potential health effects. Current toxicological information is examined to determine the types of health effects which have been reported following exposure to each of these metals (hazard identification), and to identify the levels of exposure at which the reported effects were manifested (dose-response assessment). It also makes use of multi-pathway modelling to estimate the total exposure to each of these metals which are likely to occur (exposure assessment). It then combines the toxicological and exposure information to estimate the potential health effects which may occur (risk characterization). Each of these components, hazard identification, exposure assessment, dose-response assessment and risk characterization has been described in detail in previous health risk assessment reports which have evaluated potential health risks associated with exposures to various metals in the soils in Port Colborne (MOE, 1998) and other locations in Ontario (MOE, 1991; 1999; 2001; MOEE, 1995).

The human health risk assessment includes the following components:

- *A multimedia approach*, which considers total exposure from all environmental media, was chosen to characterize the risk. The approach recognizes that contaminants are present simultaneously in food, air, water, consumer products, soil or dust.

- *The exposure pathways of concern*, which include inhalation and incidental ingestion of soil particles derived from backyard soils, dermal contact with this soil and ingestion of backyard produce. In addition, exposures to supermarket food, ambient air and drinking water are estimated. The exposure model estimates daily intakes from all exposure pathways for different age classes (infant, toddler, child, teen and adult). Food basket data included recent Canadian Market Basket Survey information and backyard vegetable data collected from the Rodney Street community.

- *Important receptors,* which include, infants, toddlers, children, teens and adults. Toddlers (aged seven months to less than five years) represent the most important receptor due to their increased exposures to soil and hand-to-mouth behaviour compared with other receptor age groups.

- *Assessment of the bioavailability of nickel (and other metals) from soil*. The relative bioavailability (bioaccessibility) of nickel (and other metals) in soil was investigated using both simulated stomach acid leach and bioaccessibility test data.

- *Dermal exposure to nickel (and other metals)*. The dermal exposure pathway was examined as an intake pathway, however, even though contact dermatitis (for nickel) is a relatively common occurrence (approximately 10%) in the general population (ie., due to contact with coinage, jewelry and stainless steel objects), oral and dermal exposure limits for this endpoint have not been developed by other regulatory agencies.

- *Toxicological assessment of nickel (and other metals)*. The dose-response assessment, assessed cancer and non-cancer exposure limits based on nickel species characterization (other metals were not speciated).

- *Development of health-based site-specific intervention levels*. An important output of the risk assessment process are intervention levels. These are tools for evaluating and cleaning up contaminated soils.

Another paradigm for evaluating the association between human health risks and exposures to chemicals and other substances or disease causing agents is epidemiology. Well documented epidemiological data has a clear advantage over animal studies, since concerns about extrapolating from animals to man do not arise. The epidemiology paradigm is based on a number of criteria for establishing causality, these include:

a) the strength of association as measured by the relative risk;
b) the consistency of the association;
c) the temporal association between cause and effect;

d) a dose-response relationship;
e) specificity of association.

Human epidemiological studies have their own set of limitations related to proving that there is a causal association between chemical exposure and effects in the population. As described in section A2-9.2.3.2, the inhalation unit risk factors for estimating lung cancer risk from inhaling nickel compounds are based on epidemiological studies of nickel refinery workers.

## 2.0 Identifying Metals of Concern

An extensive sampling program has been carried out for the homes in the Rodney Street community in Port Colborne (Part A). The monitoring program identified ten metals that are present in the soil at levels that exceed the current Ministry of the Environment guidelines for medium fine textured soil in a residential community (MOEE, 1997). The range of reported concentrations for each of the ten metals are listed in Table 2-1. The respective MOE *Table A* criteria are also listed. Because this assessment focuses on human health, metal levels were also compared to the human health specific screening values originally developed for the MOE *Table A* which are listed in the *Rationale Document* (MOEE, 1996) which is one of three supporting documents for the MOE *Guideline* (MOEE, 1997). The data in Table 2-1 shows that for seven of the ten metals including; antimony, arsenic, beryllium, cadmium, copper, lead and nickel, the highest reported concentrations exceed both the MOE *Table A* criteria and their respective human health screening value. For the remaining three metals, cobalt, selenium and zinc, the maximum levels reported in Rodney Street community soil are below their respective human health based criteria. Based on this, cobalt, selenium and zinc would not be expected to be human health concerns for the residents of the Rodney Street community. However, the previous risk assessment undertaken by the MOE included cobalt as a metal of concern. Therefore cobalt has been carried through the current assessment of exposure and risk. Selenium and zinc have not been carried through to the detailed risk assessment because the screening assessment has shown that these metals are not present in soil in sufficient quantity to undergo further assessment. Based on the screening of metals shown in Table 2-1, eight metals have identified for inclusion in the detailed assessment of exposure and risk for the Rodney Street community.

**Table 2-1: Summary of Soil Data for the Rodney Street Community**

| Metal | Concentration in Soil (µg/g)[1] | | | | MOE Cleanup Criteria[2] (µg/g) | |
|---|---|---|---|---|---|---|
| | Minimum | Median | Average | Maximum | Guideline Criterion | Human Health Screening Value |
| Antimony | 0.28 | 0.20 | 1.20 | 91.1 | 13 | 13 |
| Arsenic | 0.60 | 12.7 | 15.9 | 350 | 25 | - |
| Beryllium | 0.23 | 0.97 | 0.97 | 4.56 | 1.2 | 0.37 |
| Cadmium | 0.14 | 1.09 | 1.2 | 35.3 | 12 | 14 |
| Cobalt | 3.50 | 39.8 | 50.7 | 262 | 50 | 2,700 |
| Copper | 4.40 | 200 | 250 | 2,720 | 300 | 1,100 |
| Lead | 5.90 | 179 | 223 | 1,800 | 200 | 200 |
| Nickel | 34.6 | 1,800 | 2,540 | 17,000 | 200 | 310 |

**Table 2-1: Summary of Soil Data for the Rodney Street Community**

| Metal | Concentration in Soil (µg/g)[1] | | | | MOE Cleanup Criteria[2] (µg/g) | |
|---|---|---|---|---|---|---|
| | Minimum | Median | Average | Maximum | Guideline Criterion | Human Health Screening Value |
| Selenium | 0.23 | 0.29 | 1.29 | 19.40 | 10 | 320 |
| Zinc | 23.0 | 314 | 370 | 1,750 | 800 | 16,000 |

1: (0-20 cm; based on 1378 sample points).

2: Table A/B criteria for metals in residential/parkland soil for medium/fine textured soil.

For two of the eight metals; arsenic and lead, the MOE has undertaken detailed assessments of exposure and health risk in communities similar to the Rodney Street community (MOE, 1991; 1999; 2001; MOEE, 1995). The results of these previous assessments have been used to develop management strategies for arsenic and lead in the Rodney Street community of Port Colborne. These strategies are presented in the Recommendations and Conclusions section of the report (Section 7.0). Therefore, the human health risk assessment has focused on the remaining six metals. The detailed exposure assessment used the highest reported concentration of each metal in the soil from the Rodney Street community. The metals carried through to the risk assessment, and the soil concentrations used in the assessment are summarized in Table 2-2.

**Table 2-2: Metals Considered in the Exposure Assessment**

| Metal | Soil Concentration (µg/g) |
|---|---|
| Antimony | 91.1 |
| Beryllium | 4.56 |
| Cadmium | 35.3 |
| Cobalt | 262 |
| Copper | 2,720 |
| Nickel | 17,000 |

Because nickel is the major focus of this assessment, a review of default or generic soil guidelines for nickel in a residential context was undertaken. It is difficult to comment on the use and derivation of guidelines developed in other jurisdictions due to a lack of documentation. However, it is apparent that for the most part these guidelines are "triggers" or screening values requiring either action or further assessment, and are not generally soil intervention levels. This tiered approach is similar to the procedure outline in the MOE's guidelines for contaminated sites (MOEE, 1997).

## 3.0 Toxicity Assessment

The screening of chemicals in the soil in the Rodney Street community identified eight metals of potential concern (Section 2.0). The objectives of the toxicity assessment are:

- to provide the reader with a brief understanding of the toxicological effects that have been reported to be associated with exposure to the chemicals of concern;
- to identify whether each metal of concern is considered to have carcinogenic or non-carcinogenic effects and;
- to identify suitable exposure limits against which exposures can be compared to provide estimates of potential health risks.

The toxicological profiles are **not** intended to:

- be exhaustive examinations of all the toxicological information available for each metal;
- be used to develop exposure limits for exposure routes where no exposure limits are available, or;
- critically review and/or modify currently existing exposure limits set by Agencies such as the US EPA, WHO, Health Canada, etc.

This toxicity assessment outlines the toxicological effects that have been reported to be associated with inhalation, ingestion and dermal contact exposures to antimony, arsenic, beryllium, cadmium, cobalt, copper, lead and nickel, and identify whether each metal should be considered as a carcinogen or a non-carcinogen based on the exposure pathway. The type of exposure limit selected is dependent upon whether a compound is considered to have non-carcinogenic or carcinogenic effects, however, in some cases, eg., lead and cobalt, cancer potency factors are not available. The types of exposure limits associated with both types of compounds are discussed below (Tables 3-1 and 3-2).

The relevance of toxicological endpoints derived from animal studies to humans is a challenging task from a risk assessment perspective. The primary difficulty is that the contaminant levels the study animals are typically exposed to are much higher than exposures faced by human populations. The effects of these high exposures are assessed by a variety of histopathological methods.

In most cases, the molecular mechanisms causing the metal related adverse effects are not well understood, and in many cases, there is the uncertainty that the mechanisms leading to an adverse effect may differ between metal species as well as between the route of exposure. In addition, many animal studies are based on a metal species that is convenient to administer but may not be the one to which human populations are exposed.

The finding of adverse effects in animals is then related to human populations by the use of uncertainty factors. Uncertainty factors provide a safety margin in the extrapolation of the estimates of adverse effects when the mechanisms leading to adverse effects are not well understood (discussed in section A2-1).

The toxicological profiles also examine the effect that the route of exposure has on the toxicological activity of each compound. For some compounds, the route by which the compound enters the body can have a marked effect on the toxicological effects that occur. In cases where the toxicological effects of a chemical differ between the routes of exposure, it is necessary to assess inhalation and ingestion exposures independently. For example, exposure to beryllium, cadmium and nickel by inhalation may be carcinogenic, but the data suggests they are unlikely to be carcinogenic if the exposure is via ingestion. However, arsenic may be carcinogenic following either inhalation or ingestion exposure. Therefore, where route-specific exposure limits are available, the toxicological profiles will provide both. In cases where exposure limits are available for a single route of exposure, the toxicological profiles will not develop exposure limits by route-to-route extrapolation. Although complex route-to-route extrapolation is undertaken in some situations, it is typically discouraged by the US EPA and similar regulatory agencies because it requires detailed knowledge of pharmacokinetic and pharmacodynamic factors and extensive modelling. All of which are beyond the scope of the current assessment.

The selection of exposure limits (cancer and non-cancer) requires consideration of a number of important attributes of the available values. The framework and methodologies for developing exposure limits are well described by all major agencies.

Evaluation of any study used to estimate human health risk based on either toxicity testing in laboratory animals or an epidemiological study of exposed humans, utilizes extensive scientific criteria to determine the reliability of the testing protocols used. Other factors, such as the health of the animals during the test, the appropriate determination of toxicity endpoints, the statistical significance of any dose-response relationships found, and the occurrence of any confounding factors that affect the results are also considered. Epidemiological studies have a different set of rules to determine causal association between disease endpoints and human exposure patterns.

In terms of animal testing studies, the age of the study is not necessarily as important as the following of recognized and approved protocols for treating and exposing the animals to the substance being tested and identifying the resulting adverse effects. The statistical reliability of the data demonstrating the presence or absence of adverse health endpoints or any apparent dose-response relationship arising from the study are an important factor. More recent testing information generally benefits from more recent developments in toxicology and adds to the weight of evidence used to develop exposure limits.

Adoption of a particular animal testing (or epidemiology) study by regulatory agencies as supporting documentation for their exposure limits, is an important criterion for evaluation and selection of relevant toxicological information. Regulatory agencies then use such criteria to select studies to support the development of exposure limits (RfD, TDI, etc.). In addition, using the dose-response (or comparable extrapolation techniques from epidemiology studies), agencies apply UFs for threshold, non-cancer endpoints, or mathematical low dose extrapolation methods for non-threshold, cancer endpoints.

Expert judgement is required in both the application of uncertainty factors to the identified threshold value and the extrapolation to low dose estimates. While RfD or risk-based concentrations can be generated using all the appropriate risk assessment protocols and principles, the resulting exposure limits may not be immediately achievable. This may be due to background concentrations, intakes from specific pathways, technical feasibility or other reasons, though none of these reasons should necessarily preclude the use of well documented and reviewed exposure limits. It should be noted that just because one exposure limit is lower than another does not necessarily imply that the limit provides additional safety, since most exposure limits incorporate adequate margins of safety. Also, how an exposure limit is applied to reduce risk can have implications for the ultimate "safety" of the value. Consequently, while exposure limits from different agencies using current, reliable toxicological information may vary, any claims as to their relative safety vis-a-vis each other requires an assessment of how the exposure limits are applied.

Carcinogenic compounds, that act by damaging DNA, are generally considered to work through a non-threshold mechanism which means that an adverse effect is assumed to have the potential to occur at any level of exposure. Any exposure to a carcinogen is considered to be associated with some level of risk. At very low doses, the probability that an adverse effect (cancer) will occur is extremely small. The probability of developing cancer increases as the dose increases. Incremental increases in lifetime cancer risk are estimated by comparing the established potency for each compound with the calculated chronic daily intakes (CDI) for that compound. In addition, potential cancer risks from inhaling airborne metals can be assessed by comparing the annual average air concentration with inhalation unit risk factors from various agencies (Table 3.2).

A summary of the information contained in Appendix 2 is provided in Table 3-1 and Table 3-2. For each of the six metals selected for detailed risk assessment, the selected reference dose, toxicological end point and reference to the appropriate section of Appendix 2 is provided. These selected exposure limits have been used in conjunction with the exposure estimates (Section 4.0) to characterize potential risks (Section 5.0) associated with exposures to each of the metals in residential soil in the Rodney Street community.

### Table 3-1: Selected Exposure Limits and Toxicological End Points for Non-Carcinogenic Effects

| Assessed Compound | Route | Non-Cancer End Points | | Appendix Reference |
|---|---|---|---|---|
| | | R/D/R/C[1] | End Point | |
| Antimony | Oral | 0.4 μg/kg-day | decreased longevity and altered blood chemistry in rats | A2-2 |
| | Inhalation | $0.2\ \mu g/m^3$ | pulmonary toxicity in rats | |
| Beryllium | Oral | 2 μg/kg-day | intestinal lesions in dogs | A2-4 |
| | Inhalation | $0.02\ \mu g/m^3$ | beryllium sensitization in human populations | |
| Cadmium | Oral | 1 μg/kg-day | kidney damage in humans | A2-5 |
| | Inhalation | - | NA[2] | |
| Cobalt | Oral | 20 μg/kg-day | kidney effects in renally compromised patients | A2-6 |
| | Inhalation | $0.03\ \mu g/m^3$ | squamous metaplasia in rodent larynx | |
| Copper | Oral | 140 μg/kg-day | liver damage | A2-7 |
| | Inhalation | $2.4\ \mu g/m^3$ | inhalation chronic reference exposure limit | |
| Nickel | Oral | 20 μg/kg-day | reproductive effects and decreased body and organ weights in rats | A2-9 |
| | Inhalation | - | NA | |

1. RfD/RfC - reference dose/reference concentration.
2. NA - no value available.

### Table 3-2: Selected Cancer Potency Values for Contaminants of Concern

| Compound | Route | Cancer End Points | | | Appendix Reference |
|---|---|---|---|---|---|
| | | UR[1] | SF[2] | End Point | |
| Beryllium | Oral | - | | NA[3] | A2-4 |
| | Inhalation | $2.4 \times 10^{-3}\ (\mu g/m^3)^{-1}$ | | lung cancer in humans | |
| Cadmium | Oral | - | | NA | A2-5 |
| | Inhalation | $1.8 \times 10^{-3}\ (\mu g/m^3)^{-1}$ | | lung cancer in cadmium workers | |
| Nickel | Oral | - | | NA | A2-9 |
| | Inhalation | $2.4 \times 10^{-4}\ (\mu g/m^3)^{-1}$; $3.8 \times 10^{-4}\ (\mu g/m^3)^{-1}$ and $TC_{05}$ ($0.04\ mg/m^3$) | | lung cancer in nickel refinery workers | |

1. UR = Unit Risk = risk per (μg/L) oral or ($\mu g/m^3$) in air.
2. SF = Cancer slope factor = risk per dose body weight ie., per (μg/kg-day).
3. NA = no value available or not considered carcinogenic via oral exposure.

## 4.0 Exposure Assessment

The current assessment has been undertaken to provide interested/concerned parties with estimates of the metal exposures that could be experienced by people living in the Rodney Street community. Like all residents of Ontario, people living in the Rodney Street community are exposed to metals from a number of sources including, processed food, drinking water, dust, soil and air. In addition to these general exposures that are common to the population of Ontario, the residents of the Rodney Street community can be exposed to metals in dust, soil and in home grown produce. A detailed assessment was undertaken for people living in the Rodney Street community to develop estimates of the total daily exposure experienced by people of all ages. Specific details of exposure assessment methodologies are found in Appendices 3 to 7.

Two exposure areas not addressed in detail are occupational exposures and the indoor environment.

The MOE's mandate is to protect the environment and human health as it is related to the environment. MOE does not directly address workplace exposures. Worker safety and exposures in the workplace are regulated by the MOL (Ministry of Labour) and other groups.

The indoor setting is a complex, enclosed environment which is subject to many activities, voluntary and otherwise. In addition to impacts from the outdoor environment, a complex array of substances are released from cooking, heating, consumer products, furnishings and pets. Smoking can have a significant impact on indoor air quality. Certain hobbies and home renovation / decoration can also release contaminants into the home environment.

Jurisdictionally, various agencies have a role related to:

- whether the indoors is a workplace or not (this includes schools, daycare facilities and mixed residential / commercial situations);

- public health issues;

- home construction and consumer goods;

- whether industrial emissions, discharges or other sources of contamination impinge on the indoor environment.

In this particular assessment, the MOE focused on estimating indoor exposures that may result from outdoor air and soil from the surrounding property entering a home. Enforcement of its regulations and guidelines to protect outdoor air quality, drinking water quality and soil quality (the province only has limited jurisdiction over food quality and consumer products) is the main way that MOE protects environmental quality and human health.

## 4.1 Receptor Identification

### 4.1.1 Identification of Potential Receptors

The Rodney Street community in Port Colborne is a residential neighborhood. The properties are municipally serviced with domestic water that is not derived from groundwater in the area. People living in the homes in the Rodney Street community will be exposed to the metals present in the soil, but not to any metals that may be present in the groundwater in the area. Because this is a residential community, anybody living in the area can be expected to come into contact with metals present in the soil in the neighborhood. A list of all people who can be expected to be exposed to metals in the soil is provided in Table 4-1.

**Table 4-1: Potential Human Receptors in the Rodney Street Community**

| Potential Receptor | Activity Assumptions |
|---|---|
| Infant (0 - 6 months of age) | Assumed to be present on residential property for up to 23 hrs per day every day over each phase of a 70 year lifetime.<br>Ingested soil/dust is assumed to originate from the area with the highest reported level of each metal in soil in the Rodney Street community. Levels of indoor dust were assumed to be proportional to outdoor soil on a mass concentration basis. The ratio of soil intake to dust intake is not proportional to the ratio of the number of waking hours that a child spends outdoors versus indoors. Children spend only 15 to 30% of their waking hours playing outdoors but are assumed to be more likely ingest soil while outdoors (45% of the child's soil/dust intake is assumed to occur outdoors).<br>Soil/dust assumed to adhere to skin every day of the year.<br>All backyard produce consumed assumed to contain the 95th percentile concentration of all metal levels found and/or predicted.<br>All drinking water assumed to contain highest concentration found in the municipal drinking water treatment and distribution system.<br>All inhaled air is assumed to contain the average of reported annual average levels of each metal measured in Port Colborne or other similar sites in Ontario. |
| Toddler (7 months - <5 years) | |
| Child (5 - <12 years) | |
| Teen (12 - <20 years) | |
| Adult (20+ years) | |

### 4.1.2 Identifying Exposure Pathways

Residents in the Rodney Street community can be exposed to the metals in the soil by one of three different routes including; inhalation, ingestion and dermal contact. There are several factors that can contribute to the exposures experienced by each of these routes. For example, the ingestion of soil and the consumption of backyard produce would contribute to ingestion exposures, while skin contact with soil would contribute to dermal contact exposures. Each of these possibilities, known as exposure pathways, contribute to the total daily exposures experienced by residents. The potential exposure pathways that could contribute to these exposures are listed in Table 4-2, along with the rationale for their inclusion in the assessment. Table 4-2 also identifies exposure pathways that have not been considered and provides rationale for their exclusion from the process. In order to estimate any potential risks associated with exposure to the metals in the soil, the contribution that each included pathway makes to the total daily exposure must be assessed.

**Table 4-2: Possible Human Exposure Pathways at Rodney Street**

| Media | Exposure Route | Pathway | Retained | Rationale |
|---|---|---|---|---|
| Air | Inhalation | Inhalation of metals on re-entrained soil and dust in indoor air and outdoor air | Yes | The current assessment assumes that a person will be exposed to elevated levels of nickel and other metals in indoor and outdoor air and that the annual average from air monitoring data will be representative. |
| Soil | Ingestion | Ingestion of soil | Yes | The ingestion of metals in soil/dust represents a potential exposure pathway for residents in the Rodney Street community. |
| | | Uptake into plants and consumption of plants | Yes | Fruits and vegetables grown in backyard gardens in the Rodney Street community properties may contain metals taken up from the soil. The consumption of this produce represents a potential exposure pathway for residents in the Rodney Street community. |
| | | Uptake into animals through plants and consumption of animal products | No | The homes in the Rodney Street community are not used for the production of livestock. Therefore exposure to metals through the consumption of livestock raised on the Rodney Street properties will not occur. |
| | Dermal Uptake | Dermal contact with soil | Yes | Exposure to metals through skin contact with metal bearing soil/dust on the Rodney Street properties is a potential exposure pathway for residents in the Rodney Street community. |
| Groundwater | Ingestion | Ingestion of metals in water derived from groundwater | No | Groundwater is not used as a source of domestic supply. |
| | Dermal Uptake | Dermal contact with metals in the groundwater | No | Groundwater is not used as a source of domestic supply. |

### 4.1.3 Identifying Receptor Parameters

In addition to knowing who will be exposed to the metals in the soil and what routes contribute to the total exposure, it is necessary to have an understanding of the amount of exposure that could be expected for people in each of the age groups identified in Table 4-1. In order to accomplish this, it is necessary to characterize the physiological and behaviourial characteristics of each receptor group. For example, the amount of soil ingested will determine the level of direct exposure to metals in the soil, and the amount of air inhaled will govern the inhalation exposures experienced. These factors, and others, known as receptor parameters will govern the exposures experienced by the residents of the Rodney Street community. Several sources were considered in the selection of these parameters. The Compendium of Canadian Human Exposure

Factors for Risk Assessment (O'Connor, 1997) was used as a primary source of receptor data. This source was selected since it characterizes Canadian populations; it relies on published and reliable reference sources, such as Health Canada, Statistics Canada and the Canadian Fitness and Lifestyles Research Institute; and, has been used in the past on several assessments conducted by the Ministry and the CCME (Canadian Council of Ministers of the Environment). In cases where this data set was unable to adequately describe certain time activity patterns and/or behaviourial/physiological characteristics, other data sources, such as the US EPA Exposure Factors Handbook (US EPA, 1997) were used. A summary of receptor parameters including; body weight, inhalation rate, drinking water intake, soil ingestion, soil adhesion to skin, consumption rates for backyard garden produce, and activity patterns, used to assess exposures for the residents of the Rodney Street community are presented in Table 4-3. A detailed discussion of the selection and derivation of the values listed in Table 4-3 is provided in Appendix 6 of the report.

**Table 4-3: Receptor Parameters Used to Estimate Daily Exposures**

| Parameter | Units | Infant | Toddler | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|
| | | 0 - 0.5 yrs | 0.5 - <5 yrs | 5 - <12 yrs | 12 - <20 yrs | 20+ | |
| Number of Years | years | 0.5 | 4.5 | 7 | 8 | 50 | |
| Body Weight | kg | 8.2 | 16.5 | 32.9 | 59.7 | 70.7 | O'Connor, 1997; CCME, 2000 |
| Inhalation Rate | $m^3$/day | 2.1 | 9.3 | 14.5 | 15.8 | 15.8 | O'Connor, 1997 |
| Drinking Water Intake | L/day | 0.3 | 0.6 | 0.8 | 1 | 1.5 | O'Connor, 1997; CCME, 2000 |
| Soil Ingestion | g/day | 0.035 | 0.1 | 0.1 | 0.02 | 0.02 | US EPA, 1997; 2000; Health Canada, 1995; CEPA, 1994a |
| Soil Adhesion to Skin | $mg/cm^2$ | 0.2 | 0.2 | 0.2 | 0.07 | 0.07 | US EPA, 2000 |
| Whole Body Surface Area | $m^2$ | 0.203 | 0.344 | 0.586 | 0.908 | 1.03 | O'Connor, 1997 |
| Surface Area of Hands | $m^2$ | 0.032 | 0.043 | 0.059 | 0.08 | 0.089 | O'Connor, 1997 |
| Surface Area of Arms | $m^2$ | 0.055 | 0.089 | 0.148 | 0.223 | 0.25 | O'Connor, 1997 |
| Surface Area of Legs | $m^2$ | 0.091 | 0.169 | 0.307 | 0.497 | 0.572 | O'Connor, 1997 |
| Surface Area of Feet | $m^2$ | 0.025 | 0.043 | 0.072 | 0.108 | 0.119 | O'Connor, 1997 |
| Backyard Root Veg | g/day | 6.05 | 7.7 | 11.7 | 16.5 | 13.7 | MOEE, 1995 |
| Backyard Other Veg | g/day | 5.25 | 4.88 | 7.14 | 8.7 | 10 | MOEE, 1995 |
| Backyard Fruit | g/day | 3.96 | 6.81 | 7.8 | 7.5 | 14.1 | MOEE, 1995 |
| Supermarket Food | g/day | 822 | 1478 | 1798 | 1945 | 1598 | Health Canada, 1995 |
| Amount of time spent outdoors-summer | hrs/day | 3 | 4.3 | 4.3 | 4.3 | 3 | Derived from US EPA[1] |
| Amount of time spent outdoors-winter | hrs/day | 2 | 2 | 2 | 2 | 2 | Derived from US EPA[1] |
| Amount of time spent indoors-summer | hrs/day | 21 | 19.7 | 19.7 | 19.7 | 21 | Derived from US EPA[1] |
| Amount of time spent indoors-winter | hrs/day | 22 | 22 | 22 | 22 | 22 | Derived from US EPA |
| Amount of time spent in Rodney Street Area (July and August) | hrs/day | 23 | 23 | 23 | 23 | 23 | Derived from US EPA[1] |

**Table 4-3: Receptor Parameters Used to Estimate Daily Exposures**

| Parameter | Units | Infant | Toddler | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|
| | | 0 - 0.5 yrs | 0.5 - <5 yrs | 5 - <12 yrs | 12 - <20 yrs | 20+ | |
| Amount of time spent in Rodney Street Area (remainder of year) | hrs/day | 23 | 23 | 16 | 14 | 23 | Derived from US EPA[1] |

[1]based on time activity pattern taken from the US EPA Exposure Factors Handbook (US EPA, 1997).

### 4.1.4 Exposure Assessment Assumptions

The objective of the assessment is to provide exposure estimates that are representative of reasonable upper bound exposures that could be experienced by Rodney Street residents. When selecting these parameters and assumptions for use in the current assessment, MOE considered guidance provided in documents by RAGS (Risk Assessment Guidance for Superfund), CCME, and MOE (eg., SSRA guidelines) to estimate potential exposures that are conservative in nature, and would not be expected to underestimate potential exposures or risks to sensitive members of the Rodney Street community. A list of the assumptions used in this assessment and the effect that each will have on exposure estimates is provided in Table 4-4.

Default assumptions for human receptor characteristics are conservatively derived from extensive surveys of these characteristics in human populations and are protective of most segments of society. These human receptor characteristics are used to develop health based exposure limits (standards) and to assess the risks associated with various exposures to contaminants in air, water, soil, food and consumer products. When setting standards to protect human health and the environment under conditions of relatively low pollution (rural or urban background), assumptions about exposure to specific chemicals in air, water, soil and food assume that most of the chemical being inhaled, ingested or contacted by the skin is completely available for absorption into the body. This assumption is highly conservative and generally overestimates actual conditions and provides an additional margin of safety to the standard or risk being assessed. In reality, the amount of chemical available for absorption into the human body from any environmental medium is dependent on a complex interaction between the form and properties of the chemical and how that chemical is presented to the body. Consequently, when assessing exposures and risks where contamination of air, water or soil is elevated above background, greater attention must be paid to making exposure estimates more realistic and reassessing the validity of conservative default assumptions.

Default assumptions for human receptor characteristics can vary depending on how they are being used and the amount of information available to assess the extent of the exposure. In a situation where the assessment is preliminary and the information on exposure levels is limited, the assessment will be at the screening level and most exposure assumptions will be conservative, ie., the maximum levels in environmental media are used, all the chemical in the medium is assumed to be available for uptake and upper range receptor intake factors are applied. Use of a worst case exposure estimate approach like this is sometimes used to screen and prioritize chemicals in environmental media. The underlying assumption being that if a chemical assessed under these conditions can meet the relevant environmental criteria or exposure limits, there should be no further concern about that chemical.

In situations where knowledge of levels of chemicals in environmental media is extensive, the exposure assessment scenario can be tailored more closely to the information and a more realistic exposure estimate derived. In this situation, receptor intake factors can be more reflective of the general population and use more central estimates of the range of the receptor characteristics in the population. For example, under RAGS (Risk Assessment Guidance for Superfund) (US EPA, 1989), the US EPA recommends use of 200 mg/day for soil ingestion by children even though this is considered a screening or upper range level of intake. Use of 80 mg/day or 100 mg/day reflects a mid range level of intake and may be more appropriate and sufficiently protective. Generally, when the assessor has a better understanding of the range of exposures, a combination of mid range receptor characteristics and upper (but not maximum) measurements of environmental chemical concentrations results in exposure estimates that are realistic and protective of the population. This latter approach is what is meant by the reasonable upper bound exposure. In addition, as more information is available concerning the form (speciation) of the chemical and the environmental matrix it is found in, further adjustments can be made to take into account how much of the chemical is biologically available.

Default assumptions for human receptor characteristics and bioavailability from various environmental media have been established by major jurisdictions over the past two to three decades. When characterizing exposure, it is important that the exposure parameters are the same as the exposure limit. That is, if the exposure limit is based on doses administered to test animals (intakes) or concentrations in media that humans were exposed to, the exposure estimate should be on the same basis. If the exposure limit is based on internal or absorbed doses (uptakes), the exposure estimate should be an absorbed dose. Since the majority of exposure limits are based on administered doses or other intake estimates, exposure estimates are generally concerned with estimating how much chemical is presented to the body in air inhaled, water, food or soil ingested or skin exposure to air, water and soil. These intakes take the chemical to the place where it may be absorbed, such as the upper and lower parts of the respiratory tract, the digestive tract or the skin. The portion of soil bound metal available for uptake is termed "bioaccessible" (see Appendix 5 for further discussion). Depending on the form and chemical properties of the chemical, some proportion of the bioaccessible chemical is absorbed into the bloodstream (uptake or internal dose) and is bioavailable.

### Table 4-4: Summary of Exposure Assessment Assumptions

| Parameter | Assumption | Effect on Assessment |
|---|---|---|
| **Residency Time** | A person has been assumed to live in a residence every day for a full 70 year life-time (a total of 25550 days); and to spend up to 23 hours per day at the residence. | This approach over estimates all potential exposures because it likely underestimates the amount of time that people would be away from the home. |
| **Soil/dust Ingestion** | The rate of soil ingestion has been assumed to remain constant throughout the year. For each metal it was further assumed that all of the soil ingested in a day comes from the area of where the highest level of each individual metal was found. Adjustments were made to compensate for summer/winter and indoor/outdoor differences in soil concentrations and exposure patterns.<br>This assessment also assumed that surface soils (0 - 20 cm) are the only contributors to daily soil ingestion. | This approach will over estimate soil/dust ingestion exposures to metals because it assumes that people will have access to the soil 365 days per year. It allows for periods when access to the soil will be limited due to snow cover and ground freezing, as well as adjusting for exposure differences indoors and outdoors. It does not account for people moving about between areas of varying metal concentrations in the soil.<br>Contact with soils deeper than a few cm will be limited. |
| **Backyard Produce Consumption** | Backyard produce consumption has been assumed to occur every day throughout the year. The amount of produce grown and consumed has been estimated based on previous studies conducted by the MOE in other communities in Ontario.<br>Metal concentrations used in the current assessment were based upon the 95th percentile concentrations detected in recent sampling conducted in the Rodney Street area. | This assumption may over estimate potential exposures for people in the area who do not grow or consume home produce, or produce less than has been assumed in this assessment.<br>This assumption will likely overestimate potential exposures as most produce grown and consumed will have lower metal concentrations than those corresponding with the 95th percentile value. |
| **Skin Contact with Soil** | The total amount of skin contact with soil was assumed to take place in the area of highest reported concentration for each metal. It was also assumed that dermal contact would occur every day 365 days per year, every year over a 70 year life-time. It was also assumed that once on the skin, soil would remain in place for a full 24 hours before it was removed by washing. | This approach will over estimate exposures that occur through skin contact. It does account for periods during the year when access to the soil would be limited either through snow cover and/or ground freezing, however, it does not account for soil being washed off the skin before the end of a 24 hour period. |
| **Drinking Water Intakes** | People living in the Rodney Street community were assumed to get all domestic water from the municipal supply. Exposures were also assumed to occur every day over a 70 year life-time. The highest level of each metal reported in the drinking water was assumed to be present in the drinking water over the entire 70 year exposure period. | Using upper bound values will over estimate the drinking water exposures to metals for residents of the Rodney Street community. The maximum reported values for the 1996 to 1999 monitoring period range between 1.5 and 2 fold greater than the average levels reported over the same period (see Appendix 1). |

Continued......

## Table 4-4: Summary of Exposure Assessment Assumptions (continued)

| Parameter | Assumption | Effect on Assessment |
|---|---|---|
| **Supermarket Food** | Daily food consumption estimates developed by Health Canada for the general population were assumed to be representative of the food consumption rates and patterns for residents of the Rodney Street community. For Rodney Street community residents, it was further assumed that any backyard garden produce consumed would be in addition to the daily intakes of supermarket food. That is; the Health Canada daily consumption estimates for root and other vegetables were not lowered to account for decreases in the intakes of supermarket produce when home produce was being used. | This approach will over estimate the daily intakes of metals from produce purchased at the supermarket. The estimated daily dietary intakes of metals from supermarket foods will be marginally over estimated using this approach.<br>Daily food consumption from supermarket sources was also added to the amount of food consumption arising from home garden produce. This approach will also over estimate total daily intakes, as home garden consumption would likely cut into consumption of supermarket foods. |
| **Inhalation of Air** | Inhalation exposure to metals in the air of Port Colborne have been assumed to occur over a 24 hour period. It has been assumed that the levels of metals in indoor air are related to those found in ambient outdoor air. It was further assumed that a person would be exposed to either the highest or the average of the reported annual average levels for each metal every day over a 70 year life-time (based on the1992 through 1995 local air monitoring data).<br>This approach also assumes that the levels of metals reported in the air are present as freely available metal and are not bound to particulate matter. | This assumption will over estimate inhalation exposures to metals. Assuming a 70 year life-time residency does not allow for decreases in exposures that may occur when a person would be away from the Rodney Street community.<br>This assumption also assumes 100% bioavailability of the metal on the particulate. By assuming that the monitored levels represent metal that is available for absorption in the lung, the assessment over estimates actual doses. |
| **Inhalation of Dust** | The assessment has used ambient air monitoring data for the metals of concern. In ambient air, metals are generally bound to particulate matter. Therefore ambient air monitoring results reflect the levels of metals bound to particulates in the air and provide a truer estimate of the levels of metals present in the air than measurement of particulate matter would. | Predicted dust concentrations resulting from potential entrainment is discussed in Appendix 3. These predictions are similar to those measured in the community. |

## 4.2 Metal Concentrations in Environmental Media

As noted above, the risk assessment is intended to provide reasonable upper bound estimates of exposure for residents in the Rodney Street community. Therefore upper bound levels of each metal reported in drinking water and soil, and an upper bound level (95th percentile) for backyard garden vegetables have been used to assess potential exposures from these sources. Metal levels in ambient air are not based on the maximum reported levels, but rather on the average of reported annual average values. The rationale for these assumptions are provided in Appendix 3. The concentrations of metals in the various media are summarized in Table 4-5.

Metal levels in individual supermarket food items are not considered directly in the current assessment. Rather, the exposure assessment has relied on estimates of the total daily dietary intake of each metal provided by regulatory agencies such as Health Canada and the US EPA or detailed intake surveys published in the scientific literature. A detailed discussion of the derivation of the daily dietary intakes of metals for all age groups is provided in Appendix 4. These values have been used directly in the estimation of total daily intake for receptors in each age group.

The values listed in Table 4-5 have been used in conjunction with the daily dietary intake estimates for each metal to develop estimates of total daily exposure for all residents in the Rodney Street community.

**Table 4-5: Metal Concentrations Used to Assess Residential Exposures**

| Medium | Units | Metal Concentrations | | | | | |
|---|---|---|---|---|---|---|---|
| | | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Drinking Water | µg/L | 0.97 | 0.2 | 0.083 | 0.04 | 44 | 1.3 |
| Ambient Air | µg/m³ | 0.0011 | 0.00012 | 0.0007 | 0.002 | 0.112 | 0.033 |
| Soil | µg/g | 91.1 | 4.56 | 35.3 | 262 | 2720 | 17000 |
| Backyard Root Vegetables | µg/g | 0.021 | 0.007 | 0.063 | 0.048 | 1.92 | 2.44 |
| Backyard Other Vegetables | µg/g | 0.021 | 0.007 | 0.063 | 0.048 | 1.92 | 2.44 |
| Backyard Fruits | µg/g | 0.021 | 0.007 | 0.063 | 0.048 | 1.92 | 2.44 |

## 4.3 Metal Exposures in Individual Media

In assessing the total daily intakes of each metal of concern in the Rodney Street community, it is necessary to determine the contribution that each individual exposure pathway makes to the daily total. Each of the potential exposure pathways has been assessed individually for the residents of the Rodney Street community. These individual contributions of each pathway are then combined to provide estimates of the total daily intake of each metal from all sources for each receptor age group (Section 4.4). Exposures from the individual pathways identified in Section 4.2 are summarized in the following sections. Detailed discussions of all pathways are provided in Appendix 3 of the report.

### 4.3.1 Intake of Metals from Supermarket Foods

Estimates of the daily dietary intakes of metals from supermarket foods are generally limited and the amount of information available varies widely between metals. The metals of concern in Port Colborne include, antimony, beryllium, cadmium, cobalt, copper, and nickel. Information regarding daily dietary intakes of these metals has been taken from regulatory agencies in Canada and internationally. Additional information has been taken from the available literature. For the purposes of assessing likely daily dietary metal intakes for the residents of the Rodney Street community, preference has been given to data generated from the Canadian population. It was felt that information from Canadian sources would provide the best reflection of likely dietary habits and metal intakes for Rodney Street community residents. The daily dietary intake of metals is discussed in detail in Appendix 4. A summary of the daily dietary intake of metals for all age groups is summarized in Table 4-6. These estimates have been used in conjunction with those from the other media to develop total daily intake values for each metal (Section 4.4).

**Table 4-6: Estimated Daily Intakes of Metals from Supermarket Food**

| Receptor | Daily Intakes of Metals from Supermarket Food (µg/day) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Infant | 1.3 | 4.8 | 5.08 | 4.18 | 518 | 109.2 (72.2-146.2)* |
| Toddler | 2.3 | 8.6 | 10.6 | 7 | 822 | 190 |
| Child | 3.5 | 13.2 | 16.8 | 10 | 1230 | 251 |
| Teen | 4 | 15 | 17.3 | 12 | 1520 | 313 |
| Adult | 3.4 | 12.7 | 14.8 | 11 | 1430 | 307 |

* This range represents three separate estimates of infant dietary intakes. Refer to Table A4-4 for further details.

### 4.3.2 Intake of Metals from Drinking Water

The intake of metals from drinking water depends upon the level of metal in the water and the amount of water consumed by the average person in a day. Residents in the Rodney Street community are supplied with municipal water that is not derived from groundwater, but rather, from Lake Erie. Therefore, drinking water monitoring data for the town of Port Colborne was used to estimate the exposures to metals in drinking water for residents of the Rodney Street community. The concentration of each metal in the municipal supply is listed in Table 4-5. These values have been used to estimate the daily intake of antimony, beryllium, cadmium, cobalt, copper and nickel, for each receptor age group considered. The daily intake estimates for each metal for each age group are summarized in Table 4-7. A detailed discussion of the calculations used to estimate the daily intakes is provided in Appendix 3 of the report. The data in Table 4-7 shows that the daily intakes of most metals are generally below 1 µg/day. The notable exception is copper, where daily intakes for all age groups are greater than 1 µg/day and range between 13 and 66 µg/day. The contribution that drinking water makes to total daily exposure is discussed in Section 4.4.

**Table 4-7: Estimated Daily Intakes of Metals from Drinking Water**

| Receptor | Daily Intakes of Metals from Drinking Water (µg/day) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Infant | 0.29 | 0.06 | 0.025 | 0.012 | 13 | 0.39 |
| Toddler | 0.58 | 0.12 | 0.050 | 0.024 | 26 | 0.78 |
| Child | 0.78 | 0.16 | 0.066 | 0.032 | 35 | 1.0 |
| Teen | 0.97 | 0.2 | 0.083 | 0.040 | 44 | 1.3 |
| Adult | 1.5 | 0.3 | 0.12 | 0.060 | 66 | 2.0 |

### 4.3.3 Intake of Metals from Ambient Air

The risks associated with inhalation exposures to metals in the Rodney Street community have been assessed in two ways in this report;

First, the potential ingestion exposures associated with inhalation exposures to metal bearing particles is considered. This type of exposure is considered in this section of the report.

Second, the potential human health risks directly associated with inhaled metals were assessed by comparing the average of annual average air concentrations (1992 to 1995) in the MOE Port Colborne or Environment Canada air monitoring data for Ontario (Table A3-3, Appendix 3) with the appropriate inhalation exposure limit. This latter exposure has been directly assessed in the Risk Characterization section of the report (Section 5.0).

In Port Colborne, inhaled metals will be associated with particulate matter and will not be present as freely available metal or metal compounds. Therefore, there is a potential for the inhaled particulate matter to be cleared from the lungs, through mucocilliary transport, and swallowed. Material cleared from the lungs in this fashion will add to the total daily ingestion of metal. The amount of particulate delivered to the stomach by this process is difficult to predict with any accuracy. Therefore, to provide conservative estimates of the amount of metal ingested as a result of the clearance of inhaled particles, it has been assumed that all inhaled metal is cleared from the lung and passed to the stomach. This approach will over estimate the contribution that inhalation exposures make to the total daily intakes of metals. The reported annual average level of each metal (Table 4-5) has been used to estimate the daily ingestion intake of metals following inhalation for people living in the Rodney Street community. The rationale for using annual average ambient air quality monitoring information, and the calculations used to estimate daily intakes of each metal for each age group are discussed in detail in Appendix 3. The data in Table 4-8 shows that inhalation exposures make a very small contribution to ingestion exposures for the metals in soil in the Rodney Street community, even when it has been assumed that all inhaled material is passed to the stomach. Thus, it can be concluded that inhalation exposure to metals does not make a significant contribution to ingestion exposures to metals for the residents of the Rodney Street community. However, these intake estimates have been used in conjunction with the other values to develop total ingestion intake estimates for each metal (Section 4.4).

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**Table 4-8: Estimated Daily Intakes of Metals from Ambient Air**

| Receptor | Daily Intakes of Metals from Ambient Air (µg/day) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Infant | 0.0018 | 0.0002 | 0.0011 | 0.0033 | 0.1800 | 0.0530 |
| Toddler | 0.0081 | 0.0009 | 0.0051 | 0.0150 | 0.8200 | 0.2400 |
| Child | 0.0130 | 0.0014 | 0.0080 | 0.0230 | 1.2800 | 0.3700 |
| Teen | 0.0140 | 0.0015 | 0.0087 | 0.0250 | 1.3900 | 0.4070 |
| Adult | 0.0140 | 0.0015 | 0.0086 | 0.0250 | 1.3800 | 0.4020 |

### 4.3.4 Intake of Metals from Backyard Produce

Eating produce grown in backyards where metal levels are above typical levels, represents a potential exposure pathway if the metals present in the soil are taken up into the produce. The exposures received by people eating such produce depends upon the concentration of the metals in the produce and the amount of produce consumed from backyard gardens on an annual basis. The current assessment has assumed that backyard garden produce is consumed on a daily basis throughout the year. The amount of backyard garden produce consumed on a annually averaged daily basis is discussed in detail in Appendix 6.

As part of the ongoing work in Port Colborne, samples of backyard produce have been collected by the MOE and Jacques Whitford Environmental Limited (JWEL) from Rodney and Mitchell Streets. The levels of individual metals in the various types of produce tested are provided in Appendix 1 of this report. For the purposes of this assessment, backyard garden produce has been divided into three general categories;

| | |
|---|---|
| *root vegetables* | includes: beet root, carrot, onion and radish |
| *other vegetables* | includes: beet tops, celery, lettuce, peppers, rhubarb, squash, leeks and tomatoes |
| *fruits* | includes: pear, apple, cantaloupe, peach, plum, watermelon, and grapes |

A review of the available produce data indicated that the concentrations of metals in produce is not strongly affected by the levels of metals present in the soil and as such it was not possible to derive appropriate uptake factors for the Rodney Street area. As a result, upper bound produce concentrations measured in the area were assumed for all gardens in the assessment. With the exception of nickel, maximum values were selected due to limited data sets (see Appendix 1). For nickel, over 180 relevant plant samples were available and as a result it was considered more appropriate to select an upper bound plant concentration to represent all gardens in the assessment (Appendix 1 presents the data available at the time of this assessment). The 95th percentile concentration was selected based on the following rationale: (i) others have considered the 95th percentile of a non-normal distribution to be representative of an upper bound value (the data set appears to be log-normally distributed); (ii) the data set is highly skewed and maximum values would not be reflective of reasonable upper bound exposures; (iii) a typical diet would consist of a composite of the available produce types, while the maximum level is only reflective of a single plant type and garden location. No distinction was made for different produce types, rather the selected upper bound concentration was assumed to represent all plant types. Summaries of the daily intake estimates for each metal from root vegetables, other vegetables and fruits, for each age group are shown in Table 4-9, Table 4-10 and Table 4-11 respectively.

The intake estimates for root and other vegetables for each metal and each receptor age group, were used in conjunction with intake estimates from the other sources to develop total daily intake estimates for each metal and age group (Section 4.4).

**Table 4-9: Estimated Daily Intakes of Metals from Backyard Root Vegetables**

| Receptor | Daily Intakes of Metals from Backyard Root Vegetables (µg/day) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Infant | 0.127 | 0.04 | 0.38 | 0.29 | 12 | 15 |
| Toddler | 0.161 | 0.05 | 0.48 | 0.37 | 15 | 19 |
| Child | 0.25 | 0.08 | 0.74 | 0.56 | 22 | 29 |
| Teen | 0.35 | 0.12 | 1.0 | 0.8 | 32 | 40 |
| Adult | 0.29 | 0.10 | 0.86 | 0.66 | 26 | 33 |

**Table 4-10: Estimated Daily Intakes of Metals from Other Backyard Vegetables**

| Receptor | Daily Intakes of Metals from Other Backyard Vegetables (µg/day) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Infant | 0.11 | 0.037 | 0.33 | 0.25 | 10.1 | 13 |
| Toddler | 0.10 | 0.034 | 0.31 | 0.23 | 9.4 | 12 |
| Child | 0.15 | 0.050 | 0.45 | 0.34 | 14 | 17 |
| Teen | 0.18 | 0.061 | 0.55 | 0.42 | 17 | 21 |
| Adult | 0.21 | 0.070 | 0.63 | 0.50 | 19 | 24 |

**Table 4-11: Estimated Daily Intakes of Metals from Backyard Fruits**

| Receptor | Daily Intakes of Metals from Backyard Fruits (µg/day) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Infant | 0.08 | 0.028 | 0.25 | 0.19 | 7.6 | 10 |
| Toddler | 0.14 | 0.048 | 0.43 | 0.33 | 13.1 | 17 |
| Child | 0.16 | 0.055 | 0.49 | 0.37 | 15 | 19 |
| Teen | 0.16 | 0.053 | 0.47 | 0.36 | 14 | 18 |
| Adult | 0.15 | 0.050 | 0.45 | 0.30 | 14 | 17 |

### 4.3.5 Intake of Metals from Soil

The ingestion of soil that contains metal represents a potential exposure pathway for people who live in the homes in the Rodney Street community. The daily intake of metal from soil depends upon the amount of soil ingested and the level of metal bound to soil particles. The soil monitoring program conducted by the MOE in the Rodney Street community showed that metal levels in the soil varied across the community. It also showed that metal levels in soil varied across the sampling horizon of 20 cm. The results of the sampling program are discussed in detail in Part A. A summary of the soil monitoring results is presented in Appendix 1 of this report. Because elevated levels of metals appear to be confined to the top 20 cm of soil, it is possible that typical gardening activities could bring materials to the surface and thereby be available for exposure. Therefore, the highest level of each metal reported in the top 20 cm of soil was used to assess exposure for residents of the Rodney Street community. This approach will provide conservative estimates of reasonable upper bound exposures for all receptor age groups.

In addition to the amount of metal ingested with soil, the effective intake of metal is also dependent upon the amount of metal released from the soil during digestion. Only metal that is released from soil into the stomach or intestines during digestion can be considered to be bioaccessible to the body and available for uptake. Any metal not released from soil is excreted in the feces and does not have the opportunity to cause adverse health effects. Therefore, in assessing exposure and potential human health risks, it is necessary to consider the amount of metal actually released from the soil into the gut and not just the total amount of metal ingested with the soil, when assessing exposures and the potential for human health effects to occur.

The metals in the soil in the Rodney Street community are generally insoluble in water and tend to remain bound to soil particles under neutral conditions (pH 6 - pH 8). However, the solubility of the metals increases under acidic conditions. Therefore, under the acidic conditions of the stomach, it is reasonable to expect that some metal will be released and be accessible to the body and available for uptake. The amount of metal released from soil from the Rodney Street community has been examined by subjecting the soil to both a simulated stomach acid digestion and bioaccessiblity testing measuring the amount of each metal released from the soil into the acid solution (Appendix 5). These results, expressed as a percentage of the total metal level in the original soil sample have been used to correct the estimates of metal intake from soil ingestion. The stomach acid leach and bioaccessibility testing used to determine the adjustment factors for each metal is discussed in detail in Appendix 5. The equations used to estimate the adjusted metal intake from ingested soil are provided in Appendix 3. The results of this assessment are summarized in Table 4-12. The estimates of daily metal intakes from ingested soil for each receptor age group have been used in conjunction with the intake estimates from other sources to provide total daily intake estimates for each metal (Section 4.4).

**Table 4-12: Estimated Daily Intakes of Metals from Soil Ingestion**

| Receptor | Daily Intakes of Metals from Soil Ingestion (µg/day) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Infant | 0.54 | 0.05 | 0.5 | 1.41 | 21.7 | 59.9 |
| Toddler | 1.54 | 0.14 | 1.42 | 4.02 | 61.9 | 171 |
| Child | 1.54 | 0.14 | 1.42 | 4.02 | 61.9 | 171 |
| Teen | 0.31 | 0.029 | 0.28 | 0.81 | 12.4 | 34.2 |
| Adult | 0.31 | 0.029 | 0.28 | 0.81 | 12.4 | 34.2 |

### 4.3.6 Dermal Contact with Metals in Soil

Daily contact with metals through soil present on the skin represent a potential route of exposure. However, the insoluble nature of most metals in soil limits their bioaccessibility for uptake into and through the skin. Where data is available, it shows that dermal uptake of metals is low (Paustenbach, 2000). In determining the amount of metal that could be delivered to the skin from soil, a number of conservative assumptions have been used to provide upper bound estimates of potential exposure. It was assumed that soil on the skin would remain in place for a full 24 hour period and that bathing would only remove soil from the skin once every 24 hours. In addition, conservative or default assumptions were made regarding the amount of metal that would be released from the soil to the skin. Detailed discussions of the derivation of the dermal uptake coefficient for each metal and the calculation of the dermal contact exposures are presented in Appendix 7. The dermal contact/uptake values were assumed to represent intake values for each metal in order to facilitate their comparison with intakes from the other exposure routes. Estimates of dermal contact/intake are summarized in Table 4-13.

**Table 4-13: Estimated Daily Intakes of Metals from Dermal Contact**

| Receptor | Daily Intakes of Metals from Dermal Contact (µg/day) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Infant | 0.098 | 0.005 | 0.038 | 0.011 | 2.93 | 0.695 |
| Toddler | 0.17 | 0.0085 | 0.065 | 0.019 | 4.99 | 1.19 |
| Child | 0.28 | 0.014 | 0.11 | 0.032 | 8.23 | 1.96 |
| Teen | 0.15 | 0.0074 | 0.057 | 0.017 | 4.37 | 1.04 |
| Adult | 0.16 | 0.0079 | 0.061 | 0.018 | 4.66 | 1.11 |

## 4.4 Estimating Total Daily Intakes Of Metals

In order to estimate the potential health effects associated with exposure to metals for the residents of the Rodney Street community, it is necessary to know the total daily intakes of metals from all sources. In the Rodney Street community, two types of exposures can be considered to occur;

| | |
|---|---|
| Non Soil Related (General) Exposures: | these can be defined as; *non soil related exposures that are common across the Rodney Street community, Port Colborne and the Ontario population*. These include metal intakes from supermarket food, drinking water and ambient air. |
| Rodney Street Soil Related Exposures: | these can be defined as; *exposures that are directly affected by the metals present in the soil on the properties in the Rodney Street community*. These include metal intakes from backyard garden produce, ingestion of soil and dermal contact with soil. |

Total metal intakes from general and Rodney Street community specific exposures have been assessed separately to provide an indication of any additional exposure burdens that may be experienced by the residents of the Rodney Street community as a result of elevated levels of metals in the community. General and Rodney Street community specific exposures for each metal for all receptor age groups are provided in the following sections. In addition to providing estimates of total daily intakes on a µg/day basis, each of the following sections provide estimated daily intake (EDI) values for each receptor group on a per body weight basis, expressed as µg/kg-day. These can be considered as dose estimates and are necessary in the estimation of chronic daily intakes (CDI), which are used to estimate lifetime CDI values. Further details on the calculation of the CDI values are provided Section 5 (Risk Characterization).

### 4.4.1 Total Daily Intakes of Antimony

The contributions that general and Rodney Street community specific exposures make to the total daily intake of antimony are summarized in Table 4-14 and 4-15 respectively. The data shows that supermarket food makes the largest contribution to the total daily intake of antimony for all age groups, contributing 46% of the total exposure for the toddler receptor. It also suggests that for the toddler receptor, general exposures (air, water and market food) contribute 58% of the total exposure, with Rodney Street specific soil related pathways (soil ingestion, dermal contact and backyard produce) contributing the remaining 42% Similar trends are observed for the other receptor groups. The implications of these exposures and the potential for health effects to develop as a result of these exposures is discussed in Section 5.0.

**Table 4-14: Total Daily Intakes of Antimony: General Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|
| | Supermarket Food | Drinking Water | Ambient Air | | | |
| Infant | 1.3 | 0.29 | 0.0018 | 1.59 | 8.2 | 0.19 |
| Toddler | 2.3 | 0.58 | 0.0081 | 2.89 | 16.5 | 0.18 |
| Child | 3.5 | 0.78 | 0.013 | 4.29 | 32.9 | 0.13 |
| Teen | 4 | 0.97 | 0.014 | 4.98 | 59.7 | 0.083 |
| Adult | 3.4 | 1.5 | 0.014 | 4.87 | 70.7 | 0.069 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

**Table 4-15: Total Daily Intakes of Antimony: Rodney Street Community Specific Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|---|---|
| | Root Veg | Other Veg | Fruits | Soil Ingestion | Dermal | | | |
| Infant | 0.13 | 0.11 | 0.08 | 0.54 | 0.098 | 0.96 | 8.2 | 0.12 |
| Toddler | 0.16 | 0.10 | 0.14 | 1.54 | 0.17 | 2.11 | 16.5 | 0.13 |
| Child | 0.25 | 0.15 | 0.16 | 1.54 | 0.28 | 2.38 | 32.9 | 0.07 |
| Teen | 0.35 | 0.18 | 0.16 | 0.31 | 0.15 | 1.15 | 59.7 | 0.019 |
| Adult | 0.29 | 0.21 | 0.15 | 0.31 | 0.16 | 1.12 | 70.7 | 0.016 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

### 4.4.2 Total Daily Intakes of Beryllium

The contributions that general and Rodney Street community specific exposures make to the total daily intake of beryllium are summarized in Table 4-16 and 4-17 respectively. The data shows that supermarket food and drinking water make the largest contributions to the total daily intakes of beryllium for all receptor groups, contributing more than 96% of the total daily intake for all receptor groups. This suggests that the daily exposures to beryllium experienced by residents in the Rodney Street community of Port Colborne do not differ from those experienced by the general Ontario population. The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0.

**Table 4-16: Total Daily Intakes of Beryllium: General Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|
| | Supermarket Food | Drinking Water | Ambient Air | | | |
| Infant | 4.8 | 0.06 | 0.0002 | 4.86 | 8.2 | 0.59 |
| Toddler | 8.6 | 0.12 | 0.00088 | 8.72 | 16.5 | 0.53 |
| Child | 13.2 | 0.16 | 0.0014 | 13.4 | 32.9 | 0.41 |
| Teen | 15.0 | 0.2 | 0.0015 | 15.2 | 59.7 | 0.25 |
| Adult | 12.7 | 0.3 | 0.0015 | 13.0 | 70.7 | 0.18 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

**Table 4-17: Total Daily Intakes of Beryllium: Rodney Street Community Specific Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|---|---|
| | Root Veg | Other Veg | Fruit | Soil Ingestion | Dermal | | | |
| Infant | 0.04 | 0.037 | 0.028 | 0.050 | 0.005 | 0.16 | 8.2 | 0.0195 |
| Toddler | 0.05 | 0.034 | 0.048 | 0.14 | 0.0085 | 0.28 | 16.5 | 0.0170 |
| Child | 0.08 | 0.050 | 0.055 | 0.14 | 0.014 | 0.34 | 32.9 | 0.0103 |
| Teen | 0.12 | 0.061 | 0.053 | 0.029 | 0.0074 | 0.27 | 59.7 | 0.0045 |
| Adult | 0.10 | 0.070 | 0.050 | 0.029 | 0.0079 | 0.26 | 70.7 | 0.0036 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

### 4.4.3 Total Daily Intakes of Cadmium

The contributions that general and Rodney Street community specific exposures make to the total daily intake of cadmium are summarized in Table 4-18 and 4-19 respectively. The data shows that supermarket food makes the largest contributions to total daily intakes for all age groups. For the toddler receptor, general exposures (air, water and market food) contribute 80% of the total exposure, with Rodney Street specific soil related pathways (soil ingestion, dermal contact and backyard produce) contributing the remaining 20%. Similar trends are observed for the other receptor groups. The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0.

**Table 4-18: Total Daily Intakes of Cadmium: General Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|
| | Supermarket Food | Drinking Water | Ambient Air | | | |
| Infant | 5.08 | 0.025 | 0.0011 | 5.11 | 8.2 | 0.62 |
| Toddler | 10.6 | 0.05 | 0.0051 | 10.7 | 16.5 | 0.65 |
| Child | 16.8 | 0.066 | 0.008 | 16.9 | 32.9 | 0.51 |
| Teen | 17.3 | 0.083 | 0.0087 | 17.4 | 59.7 | 0.29 |
| Adult | 14.8 | 0.13 | 0.0086 | 14.9 | 70.7 | 0.21 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

**Table 4-19: Total Daily Intakes of Cadmium: Rodney Street Community Specific Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|---|---|
| | Root Veg | Other Veg | Fruits | Soil Ingestion | Dermal | | | |
| Infant | 0.38 | 0.33 | 0.25 | 0.50 | 0.038 | 1.50 | 8.2 | 0.18 |
| Toddler | 0.48 | 0.31 | 0.43 | 1.42 | 0.065 | 2.71 | 16.5 | 0.164 |
| Child | 0.74 | 0.45 | 0.49 | 1.42 | 0.11 | 3.21 | 32.9 | 0.098 |
| Teen | 1.0 | 0.55 | 0.47 | 0.28 | 0.057 | 2.36 | 59.7 | 0.039 |
| Adult | 0.86 | 0.63 | 0.45 | 0.28 | 0.061 | 2.28 | 70.7 | 0.032 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

### 4.4.4 Total Daily Intakes of Cobalt

The contributions that general and Rodney Street community specific exposures make to the total daily intake of cobalt are summarized in Table 4-20 and 4-21 respectively. The data shows that supermarket food makes the largest contributions to total daily intakes for all age groups. For the toddler receptor, general exposures (air, water and market food) contribute 59% of the total exposure, with Rodney Street specific soil related pathways (soil ingestion, dermal contact and backyard produce) contributing the remaining 41%. Similar trends are observed for the other receptor groups. The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0.

**Table 4-20: Total Daily Intakes of Cobalt: General Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|
| | Supermarket Food | Drinking Water | Ambient Air | | | |
| Infant | 4.18 | 0.012 | 0.0033 | 4.20 | 8.2 | 0.51 |
| Toddler | 7.00 | 0.024 | 0.015 | 7.04 | 16.5 | 0.43 |
| Child | 10.0 | 0.032 | 0.023 | 10.1 | 32.9 | 0.31 |
| Teen | 12.0 | 0.040 | 0.025 | 12.1 | 59.7 | 0.20 |
| Adult | 11 | 0.060 | 0.025 | 11.1 | 70.7 | 0.16 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

**Table 4-21: Total Daily Intakes of Cobalt: Rodney Street Community Specific Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|---|---|
| | Root Veg | Other Veg | Fruits | Soil Ingestion | Dermal | | | |
| Infant | 0.29 | 0.25 | 0.19 | 1.41 | 0.011 | 2.15 | 8.2 | 0.26 |
| Toddler | 0.37 | 0.23 | 0.33 | 4.02 | 0.019 | 4.97 | 16.5 | 0.30 |
| Child | 0.56 | 0.34 | 0.37 | 4.02 | 0.032 | 5.32 | 32.9 | 0.16 |
| Teen | 0.80 | 0.42 | 0.36 | 0.81 | 0.017 | 2.41 | 59.7 | 0.040 |
| Adult | 0.66 | 0.50 | 0.30 | 0.81 | 0.018 | 2.29 | 70.7 | 0.032 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

### 4.4.5 Total Daily Intakes of Copper

The contributions that general and Rodney Street community specific exposures make to the total daily intake of copper are summarized in Table 4-22 and 4-23 respectively. The data shows that supermarket food makes the largest contributions to total daily intakes for all age groups. For the toddler receptor, general exposures (air, water and market food) contribute 89% of the total exposure, with Rodney Street specific soil related pathways (soil ingestion, dermal contact and backyard produce) contributing the remaining 11%. Similar trends are observed for the other receptor groups. The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0.

**Table 4-22: Total Daily Intakes of Copper: General Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|
| | Supermarket Food | Drinking Water | Ambient Air | | | |
| Infant | 518 | 13.2 | 0.183 | 531 | 8.2 | 65 |
| Toddler | 822 | 26.5 | 0.820 | 849 | 16.5 | 51 |
| Child | 1230 | 35.3 | 1.28 | 1267 | 32.9 | 38 |
| Teen | 1520 | 44.1 | 1.39 | 1565 | 59.7 | 26 |
| Adult | 1430 | 66.2 | 1.38 | 1498 | 70.7 | 21 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

**Table 4-23: Total Daily Intakes of Copper: Rodney Street Community Specific Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|---|---|
| | Root Veg | Other Veg | Fruits | Soil Ingestion | Dermal | | | |
| Infant | 12 | 10.1 | 7.6 | 21.7 | 2.93 | 54.3 | 8.2 | 7 |
| Toddler | 15 | 9.4 | 13.1 | 61.9 | 4.99 | 104.4 | 16.5 | 6 |
| Child | 22 | 14 | 15 | 61.9 | 8.23 | 121.1 | 32.9 | 4 |
| Teen | 32 | 17 | 14 | 12.4 | 4.37 | 79.8 | 59.7 | 1 |
| Adult | 26 | 19 | 14 | 12.4 | 4.66 | 76.1 | 70.7 | 1.1 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

### 4.4.6 Total Daily Intakes of Nickel

The contributions that general and Rodney Street community specific exposures make to the total daily intake of nickel are summarized in Table 4-24 and 4-25 respectively. The data shows that while supermarket food makes the largest single contribution to total daily nickel intakes for all receptor age groups, Rodney Street community specific exposures also make a significant contribution. For the toddler receptor, general exposures (air, water and market food) contribute 47% of the total exposure, with Rodney Street specific soil related pathways (soil ingestion, dermal contact and backyard produce) contributing the remaining 53%. Similar trends are observed for the other receptor groups. For the assessment of exposures in the Rodney Street community, gastro-intestinal absorption of nickel was assumed to be 100% for both food and drinking water sources.

The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0.

**Table 4-24: Total Daily Intakes of Nickel: General Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|
| | Supermarket Food | Drinking Water | Ambient Air | | | |
| Infant | 109 | 0.39 | 0.053 | 109 | 8.2 | 13 |
| Toddler | 190 | 0.78 | 0.24 | 191 | 16.5 | 12 |
| Child | 251 | 1.04 | 0.37 | 252 | 32.9 | 8 |
| Teen | 313 | 1.30 | 0.41 | 315 | 59.7 | 5.3 |
| Adult | 307 | 1.95 | 0.41 | 309 | 70.7 | 4.4 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

**Table 4-25: Total Daily Intakes of Nickel: Rodney Street Community Specific Exposures**

| Receptor | Intake for Individual Media (µg/day) | | | | | Total (µg/day) | Body Weight (kg) | EDI[1] (µg/kg-day) |
|---|---|---|---|---|---|---|---|---|
| | Root Veg | Other Veg | Fruits | Soil Ingestion | Dermal | | | |
| Infant | nc | nc | nc | 59.9 | 0.695 | 61 | 8.2 | 7.4 |
| Toddler | 19 | 12 | 17 | 171 | 1.19 | 220 | 16.5 | 13.3 |
| Child | 29 | 17 | 19 | 171 | 1.96 | 238 | 32.9 | 7.2 |
| Teen | 40 | 21 | 18 | 34.2 | 1.04 | 114 | 59.7 | 1.9 |
| Adult | 33 | 24 | 17 | 34.2 | 1.11 | 109 | 70.7 | 1.5 |

1: EDI = Estimated Daily Intake expressed in µg/kg-day.

nc = home garden was not considered for the infant (see Appendix 3).

## 5.0 Risk Characterization

The potential health risks for residents of the Rodney Street community were characterized using two procedures:

1). The general and Rodney Street community specific exposures were combined into the total metal intake from all exposure pathways and were compared with the oral exposure limit (R*f*D, etc.) (Table 3-1) selected for that metal;

2). Potential health risks from inhaling airborne metals were assessed by comparing the annual average air concentration in the MOE air monitoring data for Port Colborne or Environment Canada air monitoring data for Ontario (Table A3-3) with the selected inhalation exposure limit (R*f*C, unit cancer risk, etc.) (Table 3-1 and Table 3-2).

In order to compare the estimated daily exposures to each metal calculated for each of the receptor age groups, it is necessary to convert the individual exposures into a life-time averaged chronic daily intake ($\Sigma$ CDI). The rationale for using life-time averaged daily doses for estimating the risks associated with life-time exposures is provided in Appendix 2. The total life-time CDI is calculated as shown in equation 5-1.

**Eq 5-1:**

$$Total\ CDI = \sum_{1}^{n}\left(\frac{EDI_{1..n} * Time_{1..n}}{70 years}\right)$$

| | | | | |
|---|---|---|---|---|
| Where: | Total CDI | = | Total Chronic Daily Intake | µg/kg-day |
| | $EDI_{1..n}$ | = | Estimated Daily Intake of age group n | µg/kg-day |
| | $Time_{1..n}$ | = | Time spent in each age group | years |

From equation 5-1 it can be seen that the total CDI is a sum of the fractional CDI contributions made by exposures that occur during each life stage (receptor age groups). For the purpose of this assessment, the fractional CDIs for general and Rodney Street community specific exposures have been calculated for each receptor age group (identified as CDI in the tables). The total CDIs for the general and Rodney Street community specific exposures are also listed to provide an indication of what factors make the greatest contributions to the final CDI. The final CDIs are compared to their respective oral R*f*D values in making the final estimates of potential risk. CDIs that are lower than their respective R*f*D values indicate that exposures are below the identified exposure limit and that human health effects would not be expected to occur.

Graphical representations of the EDIs for the individual receptor age groups as well as the CDI compared to the R*f*D are also provided for the six metals carried through the detailed risk assessment. In comparing the individual EDI values to the R*f*D values, it should be remembered that the US EPA recommends that this serves only as a screening tool to indicate potential risk but that they are not to be considered as predictive of potential human health effects. Predictive estimates of potential risk should only be based on a comparison between the CDI and the R*f*D (US EPA, 1989). For non-carcinogenic end points, the conservative approach of assessing the situation on the basis of the most sensitive receptor age group (from an outdoor soil exposure perspective) has been undertaken for this assessment. In cases where a particular age group exceeds the established health benchmark from general exposures alone, chemical and receptor specific factors are considered to determine the relevance and health significance of this exceedance. In general, this situation will only arise for the infant receptor group, which is a very short duration age group (<6 months) and the relevance of a life-time R*f*D to an exposure of this duration is questionable.

In the Rodney Street community HHRA, life-time cancer risks based on inhaling ambient air levels of several metals that are potentially carcinogenic (Be, Cd and Ni) were estimated by comparing inhalation intakes with cancer slope factors (risk per (µg/kg/day)) or unit risk (risk per µg/m$^3$). This is in accordance with risk assessment procedures used by US EPA and WHO (World Health Organization).

### Development of Health-Based Site Specific Intervention Levels

An important outcome of characterizing the risk is determining the need for developing an intervention level which would be used as a tool in evaluating and cleaning up contaminated soils. The need for developing such a level is based on a number of key considerations including:

1) the nature, extent and duration of the risk and the uncertainties in how these are estimated;

2) evidence or lack of evidence of actual harm to health in the community;

3) outcomes of assessments in other communities with similar or higher levels of exposure.

These considerations are not exclusive, and other legal, financial and community concern based issues, may also have an important role in developing intervention levels.

In cases where exposures to a particular metal exceed the established health benchmark, a site specific soil intervention level may be set at the soil concentration at which the combined site specific exposure to the metal from all exposure pathways experienced by the most sensitive receptor age group either approaches or exceeds the established health benchmark.

## 5.1 Antimony

### 5.1.1 Ingestion Exposure to Antimony

To characterize the potential health risks for residents of the Rodney Street community, the total antimony intake from all exposure pathways (Table 5-1) was compared with the 0.4 µg/kg-day oral exposure limit (US EPA IRIS, 1998a - oral R*f*D assessment last revised 1991; WHO, 1996) (Table 3-1).

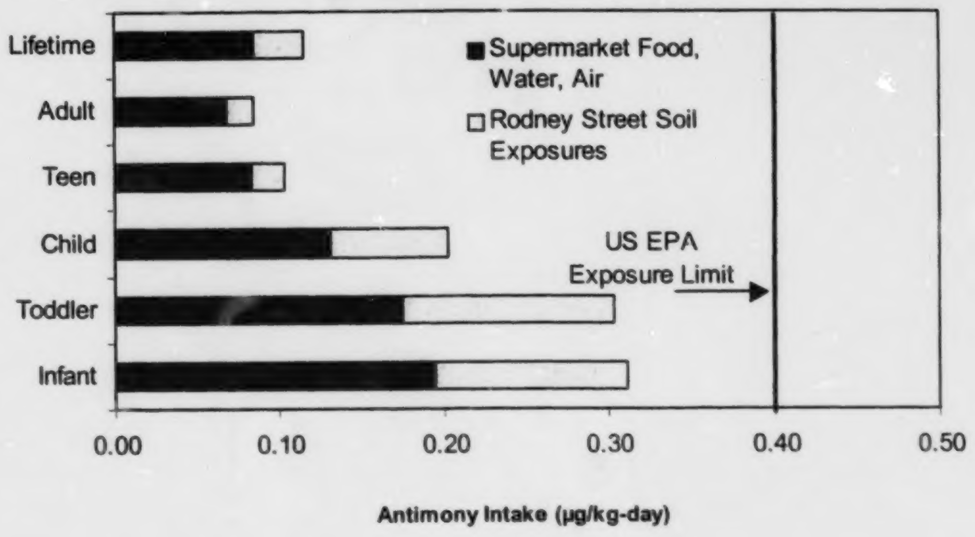
**Table 5-1: Life-time Averaged Daily Antimony Intakes for the Rodney Street Community**

| Metal | Receptor | Years | General Exposures | | | Rodney St Specific Exposures | | | Total CDI[4] |
|---|---|---|---|---|---|---|---|---|---|
| | | | EDI[1] | CDI*f*[2] | Σ CDI[3] | EDI[1] | CDI*f*[2] | Σ CDI[3] | |
| Antimony | 0 - 6 months | 0.5 | 0.19 | 0.001 | 0.08 | 0.12 | 0.0009 | 0.0298 | 0.11 |
| | 7 mo - <5 yrs | 4.5 | 0.18 | 0.011 | | 0.13 | 0.0084 | | |
| | 5 - <12 years | 7 | 0.13 | 0.013 | | 0.07 | 0.0070 | | |
| | 12 - <20 years | 8 | 0.083 | 0.009 | | 0.019 | 0.0022 | | |
| | 20 + years | 50 | 0.07 | 0.049 | | 0.016 | 0.0114 | | |

1. Estimated Daily Intake (µg/kg-day).
2. Chronic Daily Intake Fraction (µg/kg-day).
3. ΣCDI = sum of CDI*f* for General or Rodney Street community specific exposures (µg/kg-day).
4. Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (µg/kg-day).

Inspection of Table 5-1 and Figure 5-1 show that the presence of up to 91.1 µg/g antimony in soil in the Rodney Street community is unlikely to be associated with any adverse health effects. For the toddler, dietary intake is the predominant contributor to the total daily intake of antimony accounting for 46% of the total daily intake for the Rodney Street community, air and water pathways contribute 0.2% and 12%, respectively, and surface soil, through ingestion, dermal absorption and backyard produce, accounts for approximately 42% of the total daily intake. Similar trends are observed for the other receptor groups. The total chronic daily intake is approximately 0.1 µg/kg-day, which lies well below the R*f*D of 0.4 µg/kg-day. For the infant, the receptor with the estimated highest exposure, the total daily intake, under even these extreme conditions, is below 0.4 µg/kg-day.

**Figure 5-1: Summary of Total Exposures to Antimony**



### 5.1.2 Inhalation Exposure for Antimony

Potential health risks from inhaling airborne antimony were assessed by comparing the highest maximum and annual average air concentrations in the Environment Canada air monitoring data for Ontario (Table A3-3, Appendix 3) with the US EPA R*f*C of 0.2 µg/m$^3$ (US EPA IRIS, 1998a -inhalation R*f*C assessment last revised 1995) (Table 3-1). In this case, both the maximum antimony concentration (0.012 µg/m$^3$) and the highest annual average concentration (0.0011 µg/m$^3$) were well below the R*f*C. Consequently, there appears to be no potential for health related effects from inhalation of antimony.

## 5. 2 Beryllium

### 5.2.1 Ingestion Exposure to Beryllium

To characterize the potential health risks for residents of the Rodney Street community, the total beryllium intake from all exposure pathways (Table 5-2) was compared with the 2 µg/kg-day oral exposure limit (US EPA IRIS, 1998b - oral R*f*D assessment last revised 1998) (Table 3-1).

**Table 5-2: Life-time Averaged Daily Beryllium Intakes for the Rodney Street Community**

| Metal | Receptor | Years | General Exposures |  |  | Rodney St Specific Exposures |  |  | Total CDI[4] |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  | EDI[1] | CDIf[2] | Σ CDI[3] | EDI[1] | CDIf[2] | Σ CDI[3] |  |
| Beryllium | 0 - 6 months | 0.5 | 0.59 | 0.004 | 0.24 | 0.0198 | 0.0001 | 0.0054 | 0.24 |
|  | 7 mo - <5 yrs | 4.5 | 0.53 | 0.034 |  | 0.0174 | 0.0011 |  |  |
|  | 5 - <12 years | 7 | 0.41 | 0.041 |  | 0.0105 | 0.0011 |  |  |
|  | 12 - <20 years | 8 | 0.25 | 0.028 |  | 0.0045 | 0.0005 |  |  |
|  | 20 + years | 50 | 0.18 | 0.128 |  | 0.0036 | 0.0026 |  |  |

1. Estimated Daily Intake (µg/kg-day).
2. Chronic Daily Intake Fraction (µg/kg-day).
3. ΣCDI = sum of CDI*f* for General or Rodney Street community specific exposures (µg/kg-day).
4. Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (µg/kg-day).

Inspection of Table 5-2 and Figure 5-2 show that the presence of up to 4.56 µg/g beryllium in soil in the Rodney Street community is unlikely to be associated with any adverse health effects since these conservatively estimated total intakes did not exceed the US EPA R*f*D for any age class. Figure 5-3 shows the estimated daily intakes of beryllium on an expanded scale, to make it easier to see the relative contributions made by general exposures and those received from Rodney Street soil. From Figure 5-3 it can be seen that Rodney Street community specific exposures to beryllium in soil do not make an appreciable contribution to the total daily intakes of beryllium. For the toddler, dietary intake is the predominant contributor to the total daily intake of beryllium accounting for 97% of the total daily intake for the Rodney Street community, air and water pathways contribute 0.01% and 1.3%, respectively, and surface soil, through ingestion, dermal absorption and backyard produce, accounts for approximately 3% of the total daily intake. Similar trends are observed for the other receptor groups.

**Figure 5-2: Summary of Total Exposures to Beryllium**

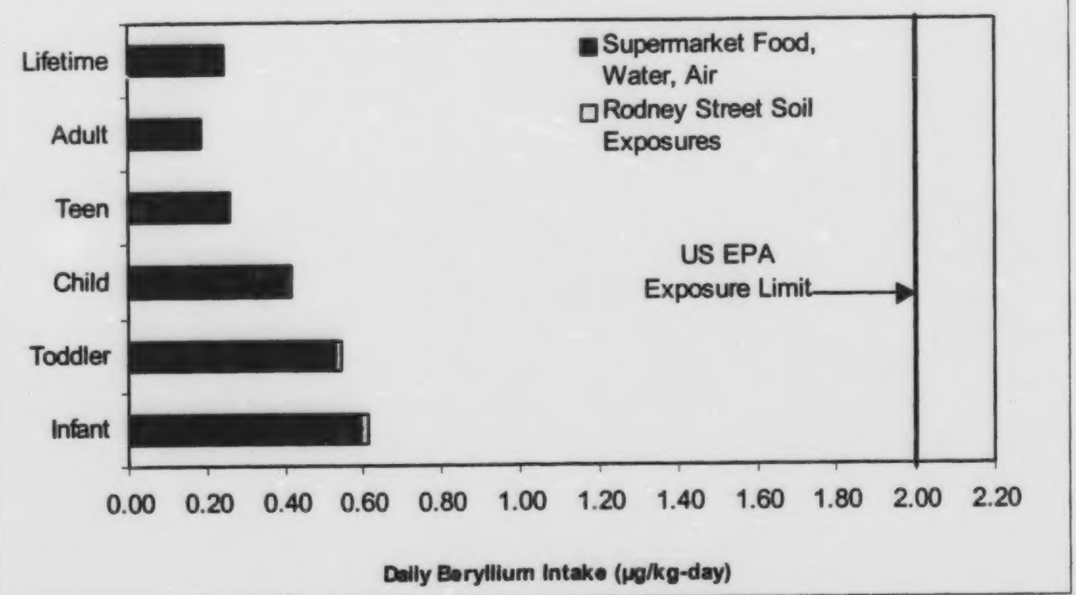
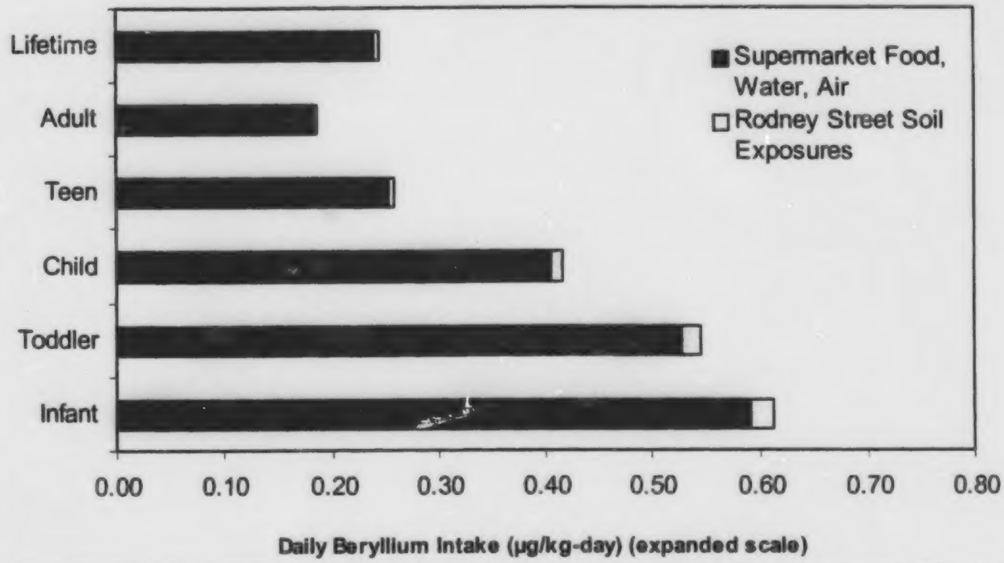


**Figure 5-3: Exposures to Beryllium (expanded scale)**



### 5.2.2 Inhalation Exposure to Beryllium

Potential health risks from inhaling airborne beryllium were assessed by comparing the estimated airborne concentration of beryllium in TSP (Total Suspended Particulate) with both the R*f*C of 0.02 µg/m$^3$ for non-cancer effects (US EPA IRIS, 1998b -inhalation R*f*C assessment last revised 1998) (Table 3-1) and with the US EPA inhalation unit risk of 0.0024 (µg/m$^3$)$^{-1}$ (US EPA IRIS, 1998b-carcinogenicity assessment last revised 1998) (Table 3-2). In both cases, the estimated airborne beryllium concentration (0.00012 µg/m$^3$) in the Rodney Street community (see Appendix 3) is less than the R*f*C and the air concentration at the $10^{-6}$ life-time cancer risk level. Consequently, there appears to be no potential for health related effects from inhalation of beryllium.

## 5.3 Cadmium

### 5.3.1 Ingestion Exposure to Cadmium

To characterize the potential health risks for residents of the Rodney Street community, the total cadmium intake from all exposure pathways (Table 5-3) was compared with the 1 µg/kg-day oral exposure limit proposed by the US EPA IRIS (1998c - oral R*f*D assessment last revised 1994) and WHO (1998a) (Table 3-1). This higher intake limit was used because intakes were estimated for all exposures not just drinking water or diet.

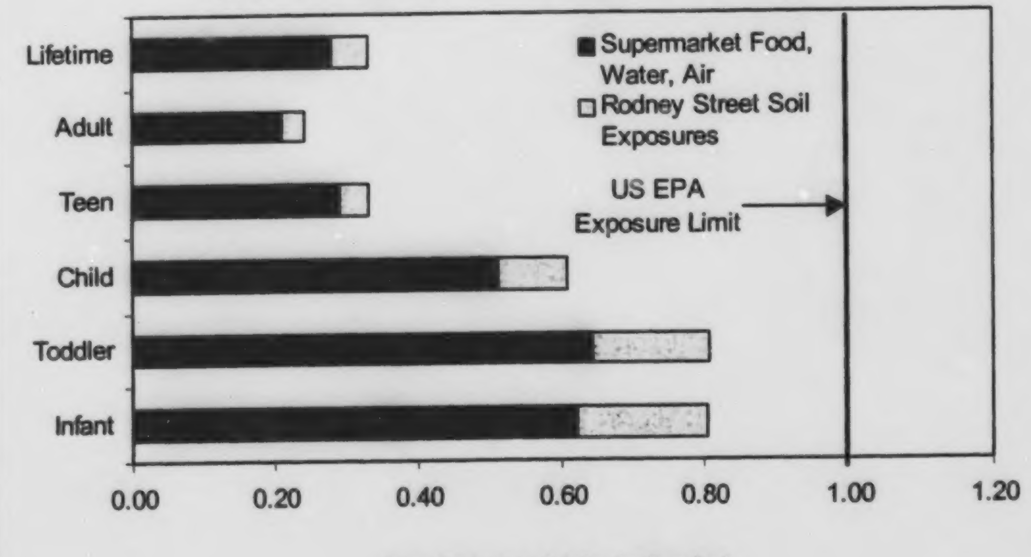
**Table 5-3: Life-time Averaged Daily Cadmium Intakes for the Rodney Street Community**

| Metal | Receptor | Years | General Exposures | | | Rodney St Specific Exposures | | | Total CDI[4] |
|---|---|---|---|---|---|---|---|---|---|
| | | | EDI[1] | CDIf[2] | Σ CDI[3] | EDI[1] | CDIf[2] | Σ CDI[3] | |
| Cadmium | 0 - 6 months | 0.5 | 0.62 | 0.004 | 0.28 | 0.18 | 0.0013 | 0.049 | 0.33 |
| | 7 mo - <5 yrs | 4.5 | 0.65 | 0.041 | | 0.164 | 0.0105 | | |
| | 5 - <12 years | 7 | 0.51 | 0.051 | | 0.098 | 0.0098 | | |
| | 12 - <20 years | 8 | 0.29 | 0.033 | | 0.040 | 0.0046 | | |
| | 20 + years | 50 | 0.21 | 0.15 | | 0.032 | 0.0229 | | |

1. Estimated Daily intake (µg/kg-day).
2. Chronic Daily Intake Fraction (µg/kg-day).
3. ΣCDI = sum of CDI*f* for General or Rodney Street community specific exposures (µg/kg-day).
4. Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (µg/kg-day).

Inspection of Table 5-3 and Figure 5-4 show that the presence of up to 35.3 µg/g cadmium in soil in the Rodney Street community is unlikely to be associated with any adverse health effects since these conservatively estimated total intakes did not exceed the US EPA R*f*D for any age class. For the toddler, dietary intake is the predominant contributor to the total daily intake of cadmium accounting for 79% of the total daily intake for the Rodney Street community, air and water pathways contribute 0.04% and 0.4%, respectively, and surface soil, through ingestion, dermal absorption and backyard produce, accounts for approximately 20% of the total daily intake. Similar trends are observed for the other receptor groups.

**Figure 5-4: Summary of Total Exposures to Cadmium**



### 5.3.2 Inhalation Exposure to Cadmium

There are no appropriate air monitoring data for cadmium in Port Colborne. Recent air monitoring at the Rodney Street site for cadmium based on less than six positive readings over a two month period yield the following interim results: average Cd concentration from TSP sampling = 0.046 μg / m$^3$ (max. = 0.3 μg / m$^3$); average Cd concentration from $PM_{10}$ sampling = 0.0002 μg / m$^3$ (max. = 0.0005 μg / m$^3$). Over this period, the airborne particulate readings were: average TSP concentration = 41.7 μg / m$^3$ (max. = 100 μg / m$^3$); average $PM_{10}$ concentration = 16.5 μg / m$^3$ (max. = 66 μg / m$^3$). The particulate data show a typical mass concentration relationship, ie., TSP mass about twice the $PM_{10}$ mass (see section A2-9.2.1.1), however, the cadmium concentrations for the $PM_{10}$ monitoring are less than 1% of the cadmium concentrations found in the TSP monitoring data. This $PM_{10}$ data is consistent with the range of federal 1995 - 1999 $PM_{10}$ cadmium air monitoring data for Ontario (average = 0.0007 μg / m$^3$ (range 0.0001 μg / m$^3$ to 0.0067 μg / m$^3$)(Table A1-3)). Potential cancer risks from inhaling airborne cadmium were can be assessed by comparing the highest average annual average air concentration in the Environment Canada air monitoring data for Ontario (Table A1-3) with the US EPA inhalation unit risk (0.0018 (μg/m$^3$)$^{-1}$ (US EPA IRIS, 1998c - carcinogenicity assessment last revised 1992) (Table 3-2). In this case, the maximum average cadmium concentration found in the 1995-1999 Environment Canada monitoring of nine sites spread across Ontario was 0.0007 μg/m$^3$, or about 1.2 x 10$^{-6}$ life-time risk.

Using the US EPA unit inhalation risk of 0.0018 (μg/m$^3$)$^{-1}$, the life-time inhalation cancer risk estimate is 1.2 x 10$^{-6}$. The WHO (2000) considers the US EPA unit risk to be a serious overestimate due to concomitant exposure to arsenic in the populations used to derive this unit risk. WHO (2000) estimates that the lowest estimate of cumulative exposure to airborne cadmium associated with lung cancer extrapolated for continuous life-time exposure is around 0.3 μg/m$^3$. Converting the Health Canada $TC_{05}$ for cadmium of 5.1 μg/m$^3$ to a unit risk factor (0.05 / 5.1 μg/m$^3$ = 9.8 X 10$^{-3}$ (μg/m$^3$)$^{-1}$), and applying this to the Environment Canada data, the life-time inhalation cancer risk estimate is 6.9 X 10$^{-6}$ at the average annual average air cadmium concentration of 0.0007 μg/m$^3$. This life-time inhalation risk estimate is six times greater than the US EPA risk estimate. Compared with the US EPA and WHO, the Health Canada approach appears to over-estimate lung cancer risk estimates for inhaled cadmium.

Two factors should be noted:

1) The Health Canada $TC_{05}$ is based on animal studies and the US EPA unit risk is based on cadmium smelter workers;

2) The use of $PM_{10}$ monitoring data to estimate lung cancer risks using unit risks based on workplace air particulate concentrations of different particle size distributions may require further adjustment (see section A2-9.2.1.1).

Until additional air concentration data for cadmium in Port Colborne air is available, the potential for lung cancer risk from this exposure cannot be reliably estimated. If cadmium concentrations in Port Colborne air are closer to the mean annual average air concentration in Ontario (0.0007 µg/m$^3$) or about one tenth the maximum value, the estimated life-time cancer risks from inhaling cadmium are in the "essentially negligible" $10^{-5}$ to $10^{-6}$ risk range.

## 5.4 Cobalt

### 5.4.1 Ingestion Exposure to Cobalt

To characterize the potential health risks for residents of the Rodney Street community, the total cobalt intake from all exposure pathways (Table 5-4) was compared with the 20 µg/kg-day oral exposure limit proposed by the US EPA Region III (Table 3.1).

**Table 5-4: Life-time Averaged Daily Cobalt Intakes for the Rodney Street Community**

| Metal | Receptor | Years | General Exposures | | | Rodney St Specific Exposures | | | Total CDI[4] |
|---|---|---|---|---|---|---|---|---|---|
| | | | EDI[1] | CDIf[2] | Σ CDI[3] | EDI[1] | CDIf[2] | Σ CDI[3] | |
| Cobalt | 0 - 6 months | 0.5 | 0.51 | 0.003 | 0.19 | 0.26 | 0.0019 | 0.065 | 0.26 |
| | 7 mo - <5 yrs | 4.5 | 0.43 | 0.027 | | 0.30 | 0.0193 | | |
| | 5 - <12 years | 7 | 0.31 | 0.031 | | 0.16 | 0.0160 | | |
| | 12 - <20 years | 8 | 0.20 | 0.022 | | 0.040 | 0.0046 | | |
| | 20 + years | 50 | 0.15 | 0.11 | | 0.033 | 0.024 | | |

1. Estimated Daily intake (µg/kg-day).
2. Chronic Daily Intake Fraction (µg/kg-day).
3. ΣCDI = sum of CDIf for General or Rodney Street community specific exposures (µg/kg-day).
4. Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (µg/kg-day).

Inspection of Table 5-4 and Figure 5-5 show that the presence of up to 262 µg/g cobalt in soil in the Rodney Street community is unlikely to be associated with any adverse health effects since these conservatively estimated total intakes did not exceed the US EPA R*f*D for any age class. Figure 5-6 shows the contributions to total daily intakes of cadmium made by general and Rodney Street community specific exposures. For the toddler, dietary intake is the predominant contributor to the total daily intake of cobalt accounting for 58% of the total daily intake for the Rodney Street community, air and water pathways contribute 0.12% and 0.2%, respectively, and surface soil, through ingestion, dermal absorption and backyard produce, accounts for approximately 41% of the total daily intake. Similar trends are observed for the other receptor groups.

**Figure 5-5: Summary of Total Exposures to Cobalt**

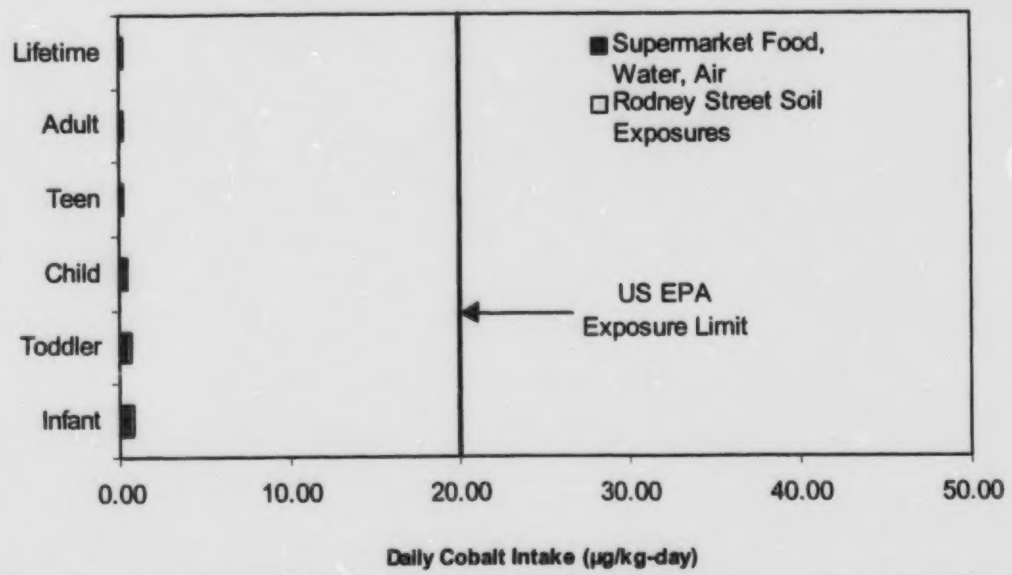
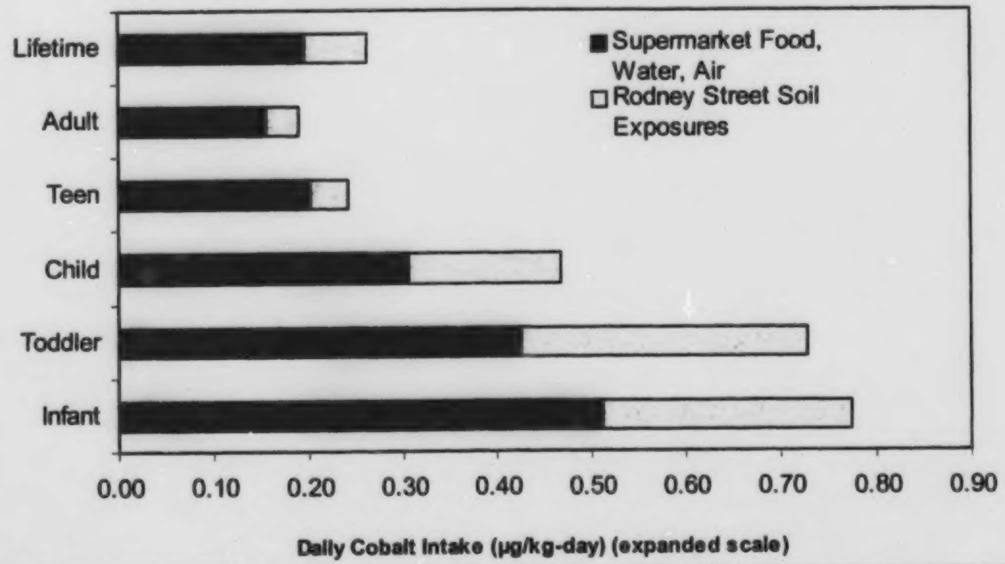


**Figure 5-6: Exposures to Cobalt (expanded scale)**



### 5.4.2 Inhalation Exposure to Cobalt

Potential health risks from inhaling airborne cobalt were assessed by comparing the highest annual average air concentration in the Environment Canada air monitoring data for Ontario (Table A3-3) with the ATSDR (Agency for Toxic Substances & Disease Registry) (1992) inhalation minimal risk level (MRL) (0.03 µg/m$^3$) (Table 3-1). In this case, the maximum cobalt concentration found in the 1995-1999 Environment Canada monitoring of nine sites spread across Ontario (0.017 µg/m$^3$) and the highest annual average concentration (0.002 µg/m$^3$), are well below this inhalation MRL. Consequently, there appears to be no potential for health related effects from inhalation of cobalt.

## 5.5 Copper

### 5.5.1 Ingestion Exposure to Copper

To characterize the potential health risks for residents of the Rodney Street community, the total copper intake from all exposure pathways (Table 5-5) was compared with the Recommended Daily Allowances (RDA) for adults (30 µg/kg-day) or children (50 µg/kg-day) and the tolerable upper intake limit of 140 µg/kg-day proposed by the WHO, 1998b and IOM (Institute of Medicine), 2001 (Table 3-1).

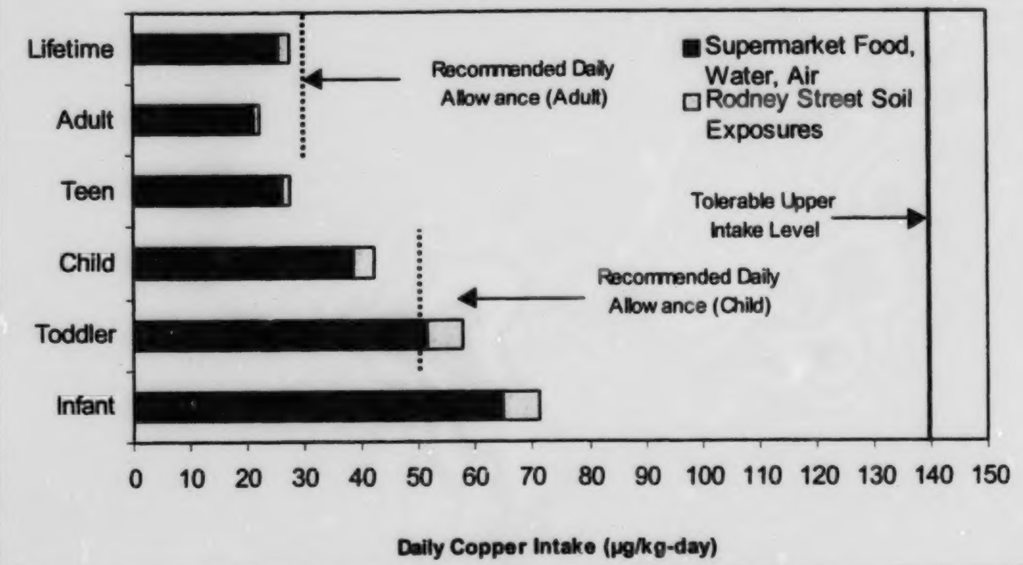
**Table 5-5: Life-time Averaged Daily Copper Intakes for the Rodney Street Community**

| Metal | Receptor | Years | General Exposures | | | Rodney St Specific Exposures | | | Total CDI[4] |
|---|---|---|---|---|---|---|---|---|---|
| | | | EDI[1] | CDI*f*[2] | Σ CDI[3] | EDI[1] | CDI*f*[2] | Σ CDI[3] | |
| Copper | 0 - 6 months | 0.5 | 65 | 0.46 | 26 | 6.6 | 0.05 | 1.8 | 27 |
| | 7 mo - <5 yrs | 4.5 | 51 | 3.3 | | 6.3 | 0.41 | | |
| | 5 - <12 years | 7 | 38 | 3.8 | | 3.7 | 0.4 | | |
| | 12 - <20 years | 8 | 26 | 3.0 | | 1.3 | 0.1 | | |
| | 20 + years | 50 | 21 | 15 | | 1.1 | 0.8 | | |

1. Estimated Daily Intake (µg/kg-day).
2. Chronic Daily Intake Fraction (µg/kg-day).
3. ΣCDI = sum of CDI*f* for General or Rodney Street community specific exposures (µg/kg-day).
4. Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (µg/kg-day).

Inspection of Table 5-5 and Figure 5-7 show that the presence of up to 2,720 µg/g copper in soil in the Rodney Street community is unlikely to be associated with any adverse health effects since these conservatively estimated total intakes did not exceed the tolerable upper intake limit for any age class. For the toddler, dietary intake is the predominant contributor to the total daily intake of copper accounting for 86% of the total daily intake for the Rodney Street community, air and water pathways contribute 0.09% and 2.8%, respectively, and surface soil, through ingestion, dermal absorption and backyard produce, accounts for approximately 11% of the total daily intake. Similar trends are observed for the other receptor groups.

**Figure 5-7: Summary of Total Exposures to Copper**



### 5.5.2 Inhalation Exposure to Copper

Potential health risks from inhaling airborne copper were assessed by comparing the highest annual average air concentration in the MOE air monitoring data for Port Colborne (Table A3-3) with the chronic air quality criteria for copper used by California (Table 3-1). In this case, the maximum copper concentration found (0.56 µg/m$^3$) and the highest annual average concentration (0.112 µg/m$^3$), are well below California's chronic inhalation reference exposure limit (REL) (2.4 µg/m$^3$) (Table 3-1). Consequently, there appears to be no potential for health related effects from inhalation of copper.

## 5.6 Nickel

### 5.6.1 Ingestion Exposure to Nickel

To characterize the potential health risks for residents of the Rodney Street community, the total nickel intake from all exposure pathways (Table 5-6), was compared with the US EPA R*f*D of 20 µg/kg-day (US EPA IRIS, 1998e - oral R*f*D assessment last revised 1996) (Table 3-1). Table 5-6 and Figure 5-8 shows that total nickel intakes are below the R*f*D for age groups over the age of five years. This situation is also true for people who live in the Rodney Street community throughout their entire life-time even when soil nickel levels are as high as 17,000 µg/g. The total chronic daily intake for people exposed to soil containing 17,000 µg/g nickel for their entire life-time averages 8.4 µg/kg-day (about 50% of the US EPA R*f*D).

**Table 5-6: Life-time Averaged Daily Nickel Intakes for the Rodney Street Community**

| Metal | Receptor | Years | General Exposures | | | Rodney St Specific Exposures | | | Total CDI[4] |
|---|---|---|---|---|---|---|---|---|---|
| | | | EDI[1] | CDIf[2] | Σ CDI[3] | EDI[1] | CDIf[2] | Σ CDI[3] | |
| Nickel | 0 - 6 months | 0.5 | 13 | 0.09 | 5.4 | 7.4 | 0.053 | 3.0 | 8.4 |
| | 7 mo - <5 yrs | 4.5 | 12 | 0.8 | | 13.0 | 0.84 | | |
| | 5 - <12 years | 7 | 8 | 0.8 | | 7.2 | 0.72 | | |
| | 12 - <20 years | 8 | 5.3 | 0.61 | | 1.9 | 0.22 | | |
| | 20 + years | 50 | 4.4 | 3.1 | | 1.6 | 1.1 | | |

1. Estimated Daily Intake (μg/kg-day).
2. Chronic Daily Intake Fraction (μg/kg-day).
3. ΣCDI = sum of CDI*f* for General or Rodney Street community specific exposures (μg/kg-day).
4. Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (μg/kg-day).

There is a great deal of uncertainty related to the assessment of infant exposures, most notably those related to soil and dietary exposures. The current assessment has defined infants as ranging from zero to six months of age. Most infants do not start moving around on their own until seven to nine months of age and as a result it is highly unlikely that infants would have much opportunity for direct soil contact. As a result, the amount of soil intake experienced by infants via the oral and dermal routes is likely minimal. To ensure conservatism these pathways were included in the assessment. With respect to food intakes, CEPA (1994b) and Dabeka (1989) have based infant diets on dietary surveys taken in the 1970s. A comparison of the infants exposures under the following scenarios is provided:

- Diet A - assumes that the infant only consumes breast milk for six months;
- Diet B - assumes that the infant only consumes formula for six months;
- Diet C - assumes that the infant consumes breast milk or formula only for the first three months, and this diet is then supplemented by vegetables (backyard garden not considered), cereal and bread, and, fruit and fruit juices.

Diet A - Recent studies of nickel in human milk using the ICP-MS analytical method indicate low levels in European mothers. Biego et al., (1998) did not detect nickel in 17 French breast milk samples at a reported detection limit of 2.9 μg/L. Krachler et al., (2000) analysed milk samples from 27 Austrian mothers and reported a median value of 0.79 μg/L (range - detection limit (0.13 μg/L) to 6.35 μg/L). In a recent Canadian study, milk from 43 mothers living in Newfoundland was analysed during the first 12 weeks of breast feeding (Friel et al., 1999). Median values for nickel ranged from 0 to 28 μg/L. If an infant consumes 850 mL breast milk per day (Emmett et al., 2000), nickel intakes resulting from Diet A could range from 0.67 μg/day to 23.8 μg/day.

Diet B - Dabeka (1989) reported milk based formulas as having half the nickel content of soy based formulas. For the 0-6 month age group, reported nickel intakes from formula range from 35.7 μg/day (evaporated milk) to 74.7 μg/day (soy based formula).

Diet C - The combination diet (Diet C) suggested above uses Nutrition Canada's values for vegetable, cereal and fruit intakes for this age group (33 g, 34.4 g and 75.7 g /day, respectively). Using the overall nickel intake for each of these food groups based on Dabeka and McKenzie (1995) and the Nutrition Canada food intake factors, this results in a nickel intake estimate of 143 μg/day. Diet A and three months of vegetable, cereal and fruit intakes suggests overall intakes of 72.2 µg/day to 95.3 µg/day over the first six months. Similarly, Diet B and three months of vegetable, cereal and fruit intakes suggests overall intakes of 107.2 µg/day to 146.2 µg/day over this period. The mid point of this range (72.2 to 146.2 µg/day) is 109.2 µg/day.

Consideration of these reasonable infant diets indicate that at 17,000 µg/g it is unlikely that the infant's exposure exceeds the established exposure limit. For the toddler exposure scenario, the estimated total daily intake is 25 µg/kg-day at the 17,000 µg/g level. A large and fixed percentage of these intake estimates is due to exposures not influenced by soil nickel concentrations (supermarket food, drinking water and ambient air; see Figure 5-9) which account for 47% of the total intake. Other age groups do not exceed the US EPA R*f*D at the 17,000 µg/g level. The relationships of total daily intake, age class and the US EPA R*f*D at 17,000 µg/g nickel in the soil are shown in Figure 5-8.

**Figure 5-8: Summary of Total Exposures to Nickel (17,000 µg/g)**

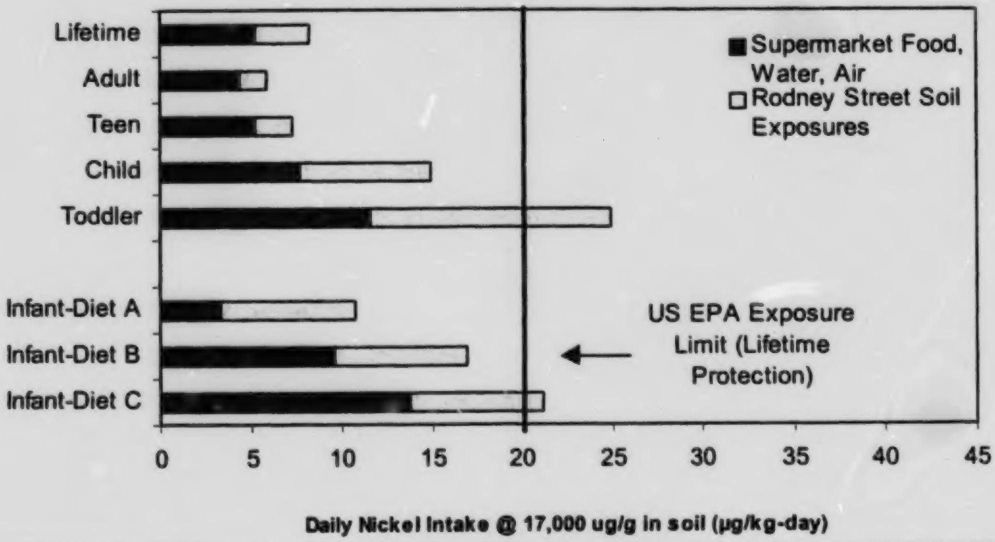
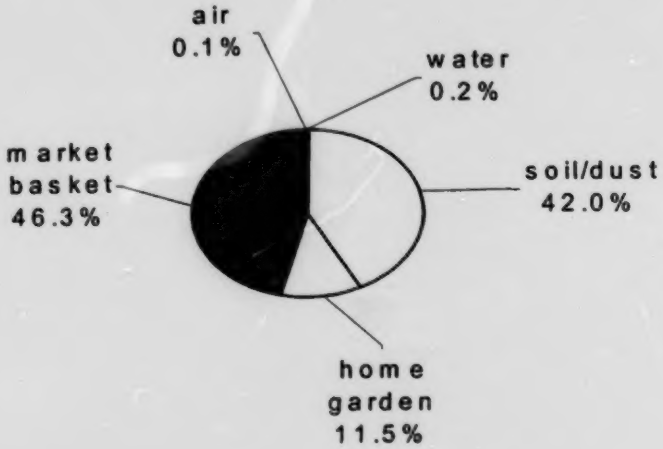


**Figure 5-9 Pathway Breakdown for the Toddler (@ 17,000 ug/g Nickel in the Soil)**



Since the toddler receptor group exceeds the US EPA R*f*D the need for an intervention level was evaluated. In the case of nickel:

> 1) The health benchmark used is the US EPA (IRIS) (1998e - oral R*f*D assessment last revised 1996) and Institute of Medicine (2001) R*f*D for soluble nickel salts. This R*f*D is for life-time protection and the endpoints of concern are reduced organ weight and reproductive endpoints found in animal studies.
>
> 2) It is generally assumed by most authorities that the R*f*D given in terms of µg / kg body weight /day is valid for children as well as for adults, while recommending that the exposure of infants and children to contaminants be kept as low as practicable. Although it is generally recognized that children may be more susceptible to the effects of contaminants than adults, the evidence often comes from differences in exposure rather than from animal studies. All major regulatory agencies (Health Canada, U.S. EPA, OECD/WHO) have placed a high priority on protecting children's environmental health. Currently, there are no standard national or international regulatory approaches for developing criteria to protect sensitive groups, such as children, although research is now underway in this area.
>
> For nickel, the most exposed life-stage is the toddler age group and as such it is considered prudent, in this case, to establish a soil intervention level that does not exceed the R*f*D for this group. Consideration of the lifetime CDI for total nickel exposures, including Rodney Street community specific exposures, indicates that by setting a soil intervention level to protect the toddler aged group, that the R*f*D would not be exceeded by older age groups.

3) At the present time, evidence of actual harm from exposure to soils containing elevated levels of nickel in the Rodney Street area is being assessed in a separate ongoing health study.

4) There are no similar assessments of other communities with similar or higher levels of nickel exposure.

At a concentration of 9,061 µg/g of nickel in the soil, the total nickel exposure (general plus Rodney Street specific) is equivalent to the R*f*D (20 µg/kg-day vs. 20 µg/kg-day) for the toddler. Under the 'reasonable' diet scenarios, the infant's exposure is less than the R*f*D as well. All the other age groups do not exceed the US EPA R*f*D at this level. The relationships of total daily intake, age class and the US EPA R*f*D, a concentration of 9,061 µg/g nickel in the soil are shown in Figure 5-10. Figure 5-11 shows that market food is still the predominate exposure pathway.

**Figure 5-10: Summary of Total Exposures to Nickel (@ 9,061 ug/g Nickel in the Soil)**

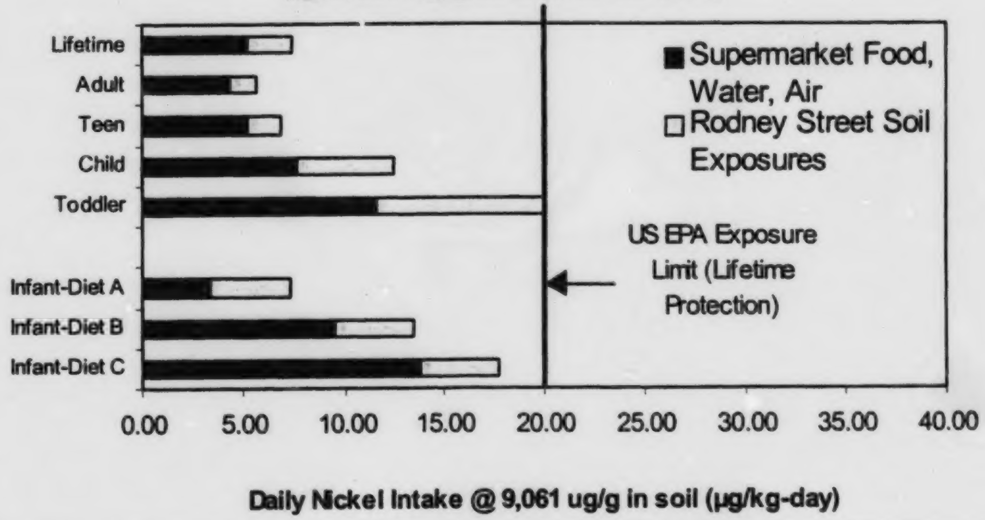
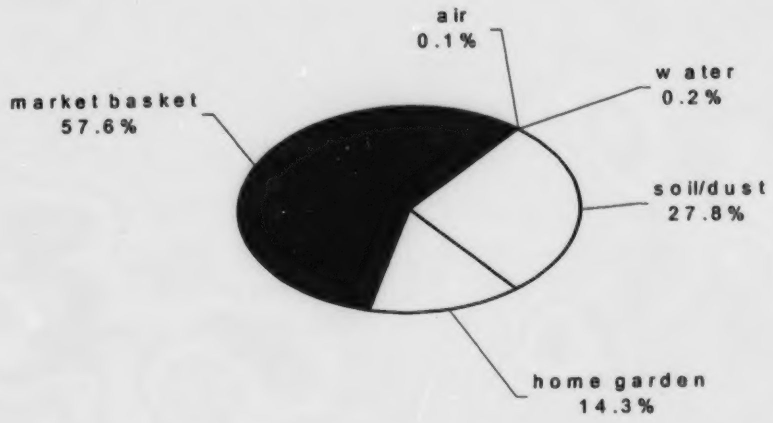


Figure 5-11 Pathway Breakdown for the Toddler (@ 9,061 ug/g Nickel in the Soil)



### 5.6.2 Inhalation Exposure to Nickel

Potential cancer risks from inhaling airborne nickel were assessed by comparing the annual average air concentrations for 1992 to 1995 in the MOE air monitoring data for Port Colborne (Table A1-2A) with inhalation unit risk factors from various agencies (Table 3.2). In this case, the mean annual average nickel concentration found was 0.033 $\mu g/m^3$. Additional air concentration data can be obtained in Appendix A1, Section A1-1.2.

Using the US EPA inhalation unit risk of $2.4 \times 10^{-4}$ $(\mu g/m^3)^{-1}$ for nickel refinery dusts (US EPA IRIS, 1998d - carcinogenicity assessment last revised 1991), the air concentration of nickel at the $10^{-5}$ life-time cancer risk (one-in-100,000) level is 0.04 $\mu g/m^3$.

Using the WHO air quality guideline for nickel (WHO, 2000), the air concentration at the $10^{-5}$ life-time cancer risk level is 0.025 $\mu g/m^3$).

Using the Health Canada $TC_{05}$ of 0.04 $mg/m^3$ for combined oxidic, sulphidic and soluble nickel, division by 5000 provides a $10^{-5}$ life-time cancer risk benchmark to judge the adequacy of indoor and ambient air (Health Canada, 1996). This $10^{-5}$ life-time cancer risk air concentration is 0.008 $\mu g/m^3$.

In each case, the predicted $10^{-5}$ life-time cancer risk air concentration ranges from 1/250,000th to 1/1,250,000th of the air nickel concentrations known to cause lung cancer in nickel refinery workers (10 $mg/m^3$) (Doll et al., 1990).

As discussed in section A2-9.2.3, all three agencies considered lung cancer mortality data from overlapping sets of occupational studies (eg., all three agencies used the Norwegian data, and both the US EPA and Health Canada also used the Ontario data). As noted in section A2-9.2.3, all the underlying epidemiology studies used by these three agencies have been updated. The fact that the predicted air concentration of nickel associated with a $10^{-5}$ life-time cancer risk ranges from 0.008 to 0.04 $\mu g/m^3$ (a five fold range) is a consequence of how each agency selected lung cancer mortality data and mathematically extrapolated the dose-response information.

The US EPA IRIS (1998d - carcinogenicity assessment last revised 1991), WHO (2000) and Health Canada (1996) inhalation unit risk factors were developed for nickel refinery dust which contains different percentages of soluble and insoluble nickel than ambient air. In order to see how representative nickel refinery dust is of Port Colborne air, a comparison of the nickel refinery dusts inhaled by workers and associated with lung and nasal cancer in these workers with airborne nickel in Port Colborne was examined (section A2-9.2.2).

It would appear that apart from the electrowinning process and nickel plating where the dust is mainly soluble nickel salts, the proportions of soluble and insoluble nickel species (ie., a large insoluble percentage) in nickel refinery dust and ambient air are comparable. Similarly, the old "total" sampler and TSP sampler data are comparable in the particle size range collected. Consequently, inhalation cancer risks estimated on this basis, are not unreasonable. However, estimates based on using unit risks with air sampler data with other particle size cut points may over or underestimate lung cancer risk potential.

To provide further context to the estimates of potential inhalation cancer risks for the 1992 to 1995 air monitoring data, it should be noted that the 1995 annual average air concentration of nickel was 0.023 $\mu g/m^3$. In addition, recent air monitoring at the Rodney Street site for nickel over a two month period yield the following interim results:

average Ni concentration from TSP sampling = 0.013 $\mu g / m^3$ (max. = 0.12 $\mu g / m^3$);

average Ni concentration from $PM_{10}$ sampling = 0.0059 $\mu g / m^3$ (max. = 0.026 $\mu g / m^3$).

Over this period, the average airborne particulate readings were: TSP concentration = 51.8 $\mu g / m^3$ (max. = 100 $\mu g / m^3$); $PM_{10}$ concentration = 22.8 $\mu g / m^3$ (max. = 66 $\mu g / m^3$). The particulate data show a typical mass concentration relationship, ie., TSP mass about twice the $PM_{10}$ mass (see section A2-9.2.1.1). The nickel concentrations for the $PM_{10}$ and TSP monitoring follow a similar relationship. This recent $PM_{10}$ nickel air monitoring data fits in with the range of federal 1995-1999 $PM_{10}$ nickel air monitoring data for Ontario (average = 0.003 $\mu g / m^3$ (range 0.0007 $\mu g / m^3$ to 0.035 $\mu g / m^3$)(Table A1-3).

Based on the above and Table A1-2a the air concentrations of nickel in Port Colborne indicate a continuing downward trend since 1992 with a corresponding lowered inhalation cancer risk.

## 5.7 Arsenic

### Human Health Significance of Measured Soil Arsenic Levels

Arsenic is a known human carcinogen. Long term chronic ingestion of arsenic has been associated with skin changes including skin cancer and is reported to increase the risk of cancer of the liver, bladder, kidney and lung (ATSDR, 1993). Major public health agencies base their quantitative assessment on skin cancer as the most critical effect. Unlike lead, exposures over the entire life-time are more important than exposures during childhood only. Because of the extensive experience with risk evaluation of arsenic in soil in other Ontario communities (Port Hope, (MOE, 1991); Deloro (MOE, 1999); and Wawa (MOE, 2001), it is considered that replication of similar calculations would not shed any light of additional value on arsenic levels in this situation. Rather, Port Colborne is compared to these other Ontario communities to determine whether the levels here are out of the ordinary and whether it is plausible that increased health risk could occur.

An important consideration regarding potential exposure to arsenic in these soils is that arsenic ions form insoluble salts with a number of cations in soils and are adsorbed by soil constituents, such as organic colloids and iron and aluminum oxides. Arsenic is held quite strongly by soils, especially fine-textured ones, and is leached very slowly. As such, relatively high levels of arsenic in soil may pose little risk if they are indeed highly insoluble and therefore not available for absorption if swallowed. In fact, the measured solubility of arsenic in these soil samples using bioaccessibility testing is 35% (Appendix 5). However, it should be noted that very low and non-detectable arsenic levels were measured in backyard vegetables.

People everywhere, including Ontario, are chronically exposed to low levels of arsenic in the environment and as such everyone has a certain amount of risk. These exposures can occur by a number of different pathways including the normal diet and drinking water. To understand the potential relevance of the measured soil levels in Port Colborne it is useful to compare the levels found with levels elsewhere in the province and in particular with the findings of health studies around arsenic conducted in the province (MOE, 1991, 1999, 2001).

The average level of arsenic in the Rodney Street community is approximately 16 µg/g, which is just below the Ontario background value of 17 µg/g which is the 98th percentile of typical urban parklands in Ontario. Out of all properties sampled there were two which had arsenic levels greater than 100 µg/g As in soil. Background soil arsenic levels in North America range from 1 to 40 µg/g. Measured arsenic levels in Port Hope, Ontario average 20 µg/g, with a maximum of around 250 µg/g (MOE, 1991). Most typical urban communities show this type of distribution with a few elevated properties within a given area. As such there is nothing unusual regarding the soil arsenic levels measured in this community. It is therefore expected that exposure, based on levels alone, would be comparable or perhaps less than other Ontario communities.

In the Port Hope risk assessment study (MOE, 1991) average soil levels were roughly double what they were in this case, with several properties in excess of 100 µg/g. Incremental cancer risk levels for soil arsenic exposure were calculated to be less than one-tenth of the calculated cancer risk from arsenic in the normal diet and determined to be non-significant. The assumed bioavailability of arsenic in soil for the Port Hope has a similar range to the arsenic bioaccessibility in Rodney Street community soils. It can be concluded that exposures to the arsenic in soil in Port Colborne would not produce a significantly different cancer risk. Also, it is not anticipated that these levels would lead to increased arsenic levels in people as measured in urine.

Similarly, a more recent health study (the most comprehensive of its kind undertaken in Ontario) considered arsenic soil contamination in the village of Deloro, Ontario (MOE 1999) where levels averaged 180 µg/g (ten fold greater than the average in the Rodney Street community) and ranged up to roughly 700 µg/g. In this study no adverse health effects were identified or predicted related to the arsenic in the village. Measured urinary arsenic levels were almost identical to a control population and there was no association between soil arsenic levels and urinary arsenic levels in residents. A detailed health survey revealed no arsenic associated health effects in the community. Further, it was estimated that removal of all arsenic in soil would reduce overall risk by no more than 4%.

Although findings in these other studies cannot be directly applied to Port Colborne because they are site specific, they do provide a reasonable context for the levels measured in Port Colborne and do suggest that contact with these soils across the range of values measured, is unlikely to result in increased exposures.

## 5.8 Lead

### Human Health Significance of Measured Soil Lead Levels

Lead in soil has long been recognized as posing potential risk, particularly to younger children ages one to four years, who may play in these areas (MOEE, 1994). Because of their higher contact rates with soil and higher rates of intestinal absorption for lead as compared with adults, young children will generally have greater exposures by this pathway. Although exposures of women of child bearing age due to fetal exposure issues merit consideration, such exposures will generally be much smaller and result in smaller absorbed intakes than for children. Therefore, young children may be considered the most susceptible receptor for exposures for direct soil/dust ingestion, and therefore characterization of risk should focus on this subgroup. Exposure to lead in soil occurs predominantly through the eating of soil or dust. Breathing of dust and skin absorption are considered trivial.

It is useful to compare the reported levels of lead in soil in this neighborhood with those in other Ontario urban areas in order to postulate whether exposures to lead here could be greater. Bearing in mind that there is no "typical" urban residential site, one may examine other Ontario residential sites in built-up areas that are not obviously associated with any lead-related industry (although the areas may have been influenced to some degree by other industry, vehicle exhaust deposition, etc.).

The mean lead content of Windsor soils was 45 µg/g with some samples approaching 300 µg/g (Weis and Barclay, 1985). In 1990, Gizyn (1995) found that lead concentrations in Windsor surface soils ranged from 23 to 128 µg/g with arithmetic and geometric means of 59 and 40 µg/g and a median concentration of 36 µg/g. Linzon (1976) reports in a survey of an Ontario downtown area, serving as control for samples collected near a lead industry, lead levels in surface soils (0-5 cm), averaging 482 µg/g with a range of 18 to 1,450 µg/g. Also, lead levels near roadways and major intersections in urban areas can exceed 500 µg/g (Rinne, 1986). O'Heany et al. (1988) reported levels of lead in surface soil from school play areas (excluding sandy and baseball diamond soils of unknown origin) in urban (Windsor and Toronto) and suburban (Scarborough and Etobicoke) Ontario. The levels ranged from 11 to 180 µg/g (average of the means 63 µg/g) in urban soils and from 6 to 81 µg/g (average of the means 21 µg/g) in suburban soils. Samples of house dust, street dust and yard soil were analyzed for lead and other elements in a survey of surficial yard soil from fifty-one homes in the Ottawa area. Lead concentrations in surficial garden soils ranged from 16 to 547 µg/g and the arithmetic and geometric means, and median concentrations were reported to be 65 µg/g, 42 µg/g and 34 µg/g, respectively (Rasmussen et al. 2001). It can thus be suggested that average surface soil lead levels in the Rodney Street community area (mean and median of 222 and 179 µg/g respectively) are in a similar range to other urban residential sites in Ontario. As well, the pattern of lead levels on these residences is consistent with very localized spots of higher (ie., > 1,000 µg/g) contamination related to leaded paint, automotive batteries or fuel use. By corollary, estimated exposures (and hence blood lead levels) would be predicted to be on average similar to those for other urban Ontario populations.

It is also relevant to discuss briefly the current scientific information relating to lead in soil and blood lead levels in young children (for review see MOEE, 1994; Davies, 1988; Stern, 1994).

This question has been examined to some extent in a number of epidemiological investigations. Some studies have found positive correlations between soil lead and blood lead levels in children, particularly where soil lead levels exceed 1,000 µg/g. Blood lead appears to vary directly with soil lead concentrations in some cases. The range of reported average slope factors (which attempt to describe this relationship numerically) is 0.6-8.0 µg/dL per 1,000 µg/g soil lead (MOEE, 1994; Davies, 1988) based on roughly 20 studies using a range of data analysis methods. For example, the study of Baltrop et al. (1975) in Derbyshire, England, concluded that soil lead contributed 0.6 (µg/dL)/(mg Pb/g soil) in a rural area where industrial point sources of lead no longer operate. Another study has demonstrated no apparent elevation in mean blood lead concentrations (compared to low exposure groups) for children in two English villages with mean soil lead levels of greater than 1,000 µg/g (Baltrop et al., 1975). In a more recent review of blood lead studies in mining areas (Steele et al., 1990) with mine waste but no recent or current history of smelting, it is noted that blood lead appear in general not to be elevated despite some very high soil lead concentrations. Average blood lead levels were lower than expected when compared with studies of urban communities or communities with operational smelters.

It is important to realize that environmental conditions greatly influence this relationship, and generally those that exhibit slope factors at the upper end of the range typically involve settings which are arid and lacking grass cover, where the soil lead will be virtually present as lead dust. These sites generally involve operating lead-based industry emissions (lead smelters, mining and battery plants). In contrast, those with the lowest slopes tend to not involve lead dusts or arid conditions. For example, in Baltrop's et al.,'s (1975) study in Derbyshire, almost all soil was grass covered and there appeared to be little influence of the soil lead upon children's blood lead levels. Although one can not rely on this pattern entirely, it would suggest that in the Rodney Street community where there is not a great deal of bare soil in sampled areas nor a lead-based industry, that a large influence on blood lead by soil lead would not be expected to be at work. For illustrative purposes only, assuming that a very high slope factor operated in this situation, say a 7- 8 µg/dL increase per 1,000 µg/g lead in soil, and knowing that background blood lead levels in Ontario children are on average 2 µg/dL, it would require soil lead levels of 1,000 µg/g or greater to cause blood lead levels to increase to the level of concern of 10µg/dL recommended by the US Center for Disease Control (CDC, 1991), Health Canada (1996) and the National Research Council (NRC, 1993b). From this perspective it can be concluded that based on a highly conservative assumption, soil levels below 1,000 µg/g should not pose an appreciable risk, whereas those at 1,000 µg/g and greater, allowing for some individual variability between different children, should be considered for risk-reduction measures. Recent blood lead data collected from children under the age of seven in the Rodney Street area support this conclusion.

The Regional Niagara Public Health Department (RNPHD, 2001) undertook ten blood lead screening test clinics between April and June 2001, for residents living or frequently spending time in the Rodney Street community area. Pregnant women, women of reproductive age and children under seven, were strongly encouraged to participate in the blood lead level screening tests. Over 1,000 people participated in the blood lead level screening tests and the results indicated there is no immediate health concern for residents showed that blood lead levels are low and similar to those found elsewhere in the province. Further, there was no correlation demonstrated between properties with elevated soil lead levels and elevated blood lead levels in residents.

The blood lead screening report concluded that children under seven years and pregnant women in the Rodney Street community are not at increased risk of lead exposure as compared to other communities in Ontario, even considering the localized elevated soil lead levels. Therefore, no immediate intervention is required regarding lead remediation in the Eastside community.

Lead may be taken up into edible plants from the soil; therefore home gardening may also contribute to exposure if the produce is grown in soil containing high lead concentrations. Simple measures such as thorough washing of vegetables prior to preparation and consumption can minimize exposure to lead on the surface of home produce. Other measures to reduce personal lead exposure are contained in the MOE's Lead in the Environment Fact Sheet.

In general based upon consideration of; a) typical urban lead levels in Ontario, b) the recently measured blood lead levels in children under the age of seven from the Rodney Street area (RNPHD, 2001) and, c) consideration of findings regarding the observed relationship between soil lead and blood lead in other communities, it can be concluded that exposure to lead in these soils should not result in undue health effects in this community. It cannot be concluded that the reported values on average would lead to undue elevation of blood lead levels overall in this community. At the same time, based upon findings in the literature it is prudent to conclude that in the few residences with reported levels above 1,000 µg/g in soil, there may be some possibility for exposures that result in some elevation in blood lead levels in children who routinely play in these areas.

### Consideration of Exposure Reduction and Intervention Levels of Lead in Soil

Individuals can very greatly reduce their exposure to lead in soil in many ways. Regular hand and face washing to remove lead dust from young children, especially before meals, can lower the possibility of accidentally swallowing lead in dust while eating. Regularly cleaning the home of tracked in soil and removal of shoes after having been in soil areas will also reduce exposure. Planting of grass, or other coverings, over bare areas of a yard can lower contact that children and pets may have with soil and the tracking of soil into homes.

With respect to identifying a specific soil lead level which requires intervention through soil removal or other form of remediation, it must be remembered that a large variety of risk factors influence lead exposure in any given situation and as such there is not one universal lead in soil standard that can be applied to all cases. Determining the specific contribution of any particular environmental variable like soil/dust to blood lead level is extremely difficult. This difficulty is also confounded by significant other factors such as socioeconomic status and dietary exposure. For instance, the numerous variables studied in Ontario blood lead studies (MOH, 1984; MOH/MOE, 1990) were unable to account for more than 30% of the variations seen in blood levels in children. The range of observations on the relationship between soil lead and blood lead seen in various studies is a further reflection of the difficulties of determining such associations. As such selection of a single value for this situation involves considerable judgement.

An intervention level or other exposure reduction controls should have some reasonably clear potential for not elevating blood lead levels in children to medical levels of concern (10 µg/dL blood lead). The range of slope factors relating soil lead to blood lead is quite wide but consideration of the upper end of the range suggests that levels of 1,000 µg/g could result in elevation of blood lead, possibly to levels of concern. As a result, it would seem prudent to err on the side of caution and select 1,000 µg/g as an intervention level for remediation/control at a residence in the absence of individual blood lead testing data for the nine residences which fall into this category. This would be applied to both bare and grass covered soils.

Another approach to development of a soil lead level of concern is to utilize multi-pathway exposure modelling. One such tool is the US EPA Integrated Uptake Biokinetic (IUBK) Model for Lead. In simple terms, this model converts estimates of lead exposure from different routes and predicts a blood lead level in children. Utilizing dietary, air, and drinking water intakes and exposure factors for Ontario populations of young children (0.5 - 4years) (MOEE, 1994) and assuming conservative soil lead bioavailability of 30%, the model predicted a soil lead concentration of 1,700 µg/g associated with a blood lead level of 10 µg/dL. Predicted blood lead levels ranged from 5.5 to 7.7 µg/dL over the soil lead range of 400 to 1,000 µg/g. This is consistent with the analysis above that suggests an intervention level of 1,000 µg/g as sufficiently protective under typical exposure conditions.

Also very relevant to the choice of an appropriate intervention level are existing regulatory standards or guidelines from other jurisdictions. Most recently US EPA (2001) has developed a new lead in soil hazard standard under section 403 of the Toxic Substances Control Act. After initial consideration of a 2,000 µg/g standard and extensive public comment, the following standards were established: a soil lead hazard standard of 400 µg/g for bare soil in play areas and an average of 1,200 µg/g for bare soil in non-play areas of the yard. The EPA view is that this is a pragmatic approach which focuses exposure reduction actions on those areas where exposures may be highest for children. This approach would appear reasonable and adoption of a similar stratified approach for this situation seems sensible. Use of a 400 µg/g soil lead level in bare soil of children's play area is prudent given the possibility of higher exposures in these areas for some children.

One other important consideration is that soil removal cannot be guaranteed to reduce actual exposure. In a comprehensive study of the effect of soil replacement on blood lead in children in the South Riverdale community of Toronto, findings could not support a beneficial effect of replacement on children living in homes that had received abatement or partial abatement (Langlois et al., 1996). In fact, 25 children who had soil replaced had a geometric mean blood lead 2.57 µg/dL higher than children that had not had soil replaced. The no abatement group also had blood lead declines over time significantly faster than the abated group. Although abatement activities may have contributed to the worse result in individuals in the abatement group, selection bias and re-contamination are likely more significant factors.

Also of note is that in other studies, eg., the Boston lead abatement project (US EPA, 1986), it is often observed that a notably elevated starting soil lead concentration (ie., in excess of 1,000 to 2,000 µg/g lead in soil) is possibly necessary to see a measurable, significant decline in blood lead. Therefore, those considering soil removal and replacement should bear in mind that the exposure reduction is unlikely to be demonstrable in sites with less than 1,000 µg/g lead in soil, but rather only theoretically reduced.

## 6.0 Discussion of Uncertainties

### 6.1 General Discussion of Uncertainty

The risk assessment process requires that many assumptions be made, either because of gaps in available monitoring data, or because of an improper or incomplete understanding of how people are likely to be exposed to the contaminants of concern. For example, when estimating daily exposures to a chemical, it is necessary to assume specific body weights in order to determine daily doses on a per body weight basis, which is necessary in order to make predictive estimates of potential health effects. However, large variations in body weights are normal between people in any of the age groups considered. The use of such assumptions results in a degree of uncertainty in the overall estimates of exposure and risk and in the final conclusions of the risk assessment. As regulators, conservative or precautionary assumptions are made to err on the side of caution and to ensure that the risk assessment does not under estimate the potential for adverse effects.

Another way of approaching uncertainty is to say "how reliable" are the conclusions of the risk assessment, or, what is the "confidence" in the process? However, when discussing the degree of confidence one holds in the results of the risk assessment, it is useful to illustrate the distinction between variability and uncertainty.

#### 1. Variability In the Data

Variability is the most common type of uncertainty found within an assessment, and is based upon the differences or diversity inherent within populations or samples of exposure parameters or individuals. Sources of variability are generally viewed the result of natural random processes, as well as environmental or genetic differences among the species or elements being evaluated. For example, the analytical results for the testing of air, water, soil and backyard produce from Port Colborne and the Rodney Street community have some degree of sampling and analytical error. Unlike uncertainty, variability in the data can be quantified statistically, and our understanding of the overall variability can be improved through further sampling exercises. To indicate the variability in the key receptor and intake parameters used in the HHRA, and, to indicate whether the value used was a central tendency, upper confidence level or maximum value, Tables 6-1 to 6-3 were prepared.

### Table 6-1: Critical Receptor Parameters Used to Estimate Daily Exposures

| Parameter | Units | Toddler | Metric | Source |
|---|---|---|---|---|
| | | 0.5 - <5 yrs | | |
| Body Weight | kg | 16.5 ± 4.5 | Mean values from empirical Canadian data. These data were derived from three Canadian surveys conducted in 1970-72, 1981 and 1988 (Demirjian 1980, CFLRI 1981, CFLRI 1988 - described in O'Connor et al., 1997). Toddler body weight was based on data from Demirjian (1980), but adjusted for evident weight increases in the Canadian population observed between 1970 and 1988. | O'Connor, 1997; CCME, 2000 |
| Inhalation Rate | $m^3$/day | 9.3 ± 2.6 | Mean inhalation rates were based on a Monte Carlo simulation incorporating quantitative time-activity data with minute volume data for various levels of physical activity for each age group considered (O'Connor, 1997). | O'Connor, 1997, |
| Drinking Water Intake | L/day | 0.6 ± 0.4 | For toddlers, Canadian data do not exist. Therefore, a mean rate was derived by calculating a weighted mean for sub-groups reported by Ershow & Cantor (1989 - cited in O'Connor, 1997) within the desired age range. | O'Connor, 1997; CCME, 2000 |
| Soil Ingestion | g/day | 0.1 | 90th percentile | EPA, 1997; 2000; Stanek et al., 2001 |
| Soil Adhesion to Skin | mg/$cm^2$ | 0.2 | 95th confidence interval | US EPA, 2000, Holmes et al., 1999 |
| Whole Body Surface Area | $m^2$ | 0.344 ± 0.043 | Mean values are based on equations developed by U.S.EPA for estimating skin surface area from measurements of weight and height; Canadian weight and height data were then employed for calculations of skin surface areas of various body parts. | O'Connor, 1997 |
| Surface Area of Hands | $m^2$ | 0.043 ± 0.005 | " | O'Connor, 1997 |
| Surface Area of Arms | $m^2$ | 0.089 ± 0.024 | " | O'Connor, 1997 |
| Surface Area of Legs | $m^2$ | 0.169 ± 0.034 | " | O'Connor, 1997 |
| Surface Area of Feet | $m^2$ | 0.043 ± 0.008 | " | O'Connor, 1997 |
| Backyard Root Veg | g/day | 7.7 | Fixed percentage of Canadian per capita food consumption rates based on assumed crop yield from a 30 $m^2$ vegetable garden (Southern Ontario). | MOEE 1995, Section A6-7 |
| Backyard Other Veg | g/day | 4.9 | " | MOEE 1995, Section A6-7 |
| Backyard Fruit | g/day | 6.8 | " | MOEE 1995, Section A6-7 |
| Supermarket Food | g/day | 1478 | Mean intakes estimated from Canadian food consumption data obtained from the 1973 Nutrition Canada National Survey. | Health Canada, 1995 |
| Amount of time spent outdoors-summer | hrs/day | 4.3 | Based on assumed time activity patterns and time spent outdoors taken from the US EPA Exposure Factors Handbook. | Section A6-8, US EPA, 1997 |
| Amount of time spent outdoors-winter | hrs/day | 2 | " | Section A6-8, US EPA, 1997 |

| Parameter | Units | Toddler | Metric | Source |
|---|---|---|---|---|
| | | 0.5 - <5 yrs | | |
| Amount of time spent indoors-summer | hrs/day | 19.7 | " | Section A6-8, US EPA, 1997 |
| Amount of time spent indoors-winter | hrs/day | 22 | " | Section A6-8, US EPA, 1997 |
| Amount of time spent in Rodney Street Area (July and August) | hrs/day | 23 | " | Section A6-8, US EPA, 1997 |
| Amount of time spent in Rodney Street Area (remainder of year) | hrs/day | 23 | " | Section A6-8, US EPA, 1997 |

## Table 6-2: Critical Environmental Nickel Concentration Parameters Used to Assess Residential Exposures

| Medium | Units | Nickel Concentrations | Metric | Source |
|---|---|---|---|---|
| Drinking Water | µg/L | 1.3 | Maximum concentration found in Port Colborne municipal drinking water distribution system (mean concentration = 0.94; range = 0.6 to 1.3). | Table A1-1 |
| Ambient Air | µg/m³ | 0.033 | Mean of annual average air concentrations measured on hi-vol TSP air samplers at Davis & Fraser for 1992-1995 (range = 0.023 to 0.053). | Table A1-2 |
| Soil | µg/g | 17000 | Maximum soil concentration at 0-20 cm depth (mean = 2544; range = 35 to 17,000). | Table A1-4 |
| Backyard Root Vegetables | µg/g | 2.44 | 95th percentile of over 180 relevant plant samples (Mean = 0.63; range = 0.03 to 5.17). | Table A1-12a and Table A1-12b |
| Backyard Other Vegetables | µg/g | 2.44 | " | Table A1-12a and Table A1-12b |
| Backyard Fruits | µg/g | 2.44 | " | Table A1-12a and Table A1-12b |
| Supermarket Food | µg/day | 190 | Based on mean nickel concentration per food item and Canadian food consumption factors. | Dabeka & McKenzie, 1995 |

**Table 6-3: Critical Receptor Intake Parameters Used to Assess Residential Exposures**

| Medium | Units | Metric | Source |
|---|---|---|---|
| Soil Bioaccessibility | % soil ingestion | The maximum mean measured soil bioaccessibility (19) under both acidic and neutral extraction conditions and both ground and unground soil samples (range = 12 to 23). | Appendix 5 and Table A5-17 |
| Indoor air to Outdoor air ratio | % outdoor air concentration | Midrange value (0.75) of several reported ratios from studies of the contribution of outdoor sources to indoor concentrations. | Section A3-1.3 |
| Indoor dust to Outdoor soil ratio | % outdoor soil concentration | Midrange value (0.39) of several reported ratios from contaminated sites and the USEPA default value for Pb in soil (0.70) (range = 0.20 to 0.70). | section A6-5.2 |
| Dermal uptake coefficient | unitless | Based on the most detailed of 3 studies of nickel penetration of excised human skin. | Appendix 7 |

### 2. Scientific Judgement

This type of uncertainty is introduced into the process when scientific judgement must be used to bridge gaps in analytical, toxicological or receptor characteristic data. For example, in estimating dermal exposure to metals it is necessary to use scientific judgement in selecting reasonable dermal uptake factors for metals where direct information is not available. In this type of situation, uncertainty in the parameter may be mitigated either by obtaining more data or by the use of conservative estimates that are applied in a consistent manner throughout the risk assessment.

Several areas of uncertainty exist within the current risk assessment. These are discussed in the following sections. In addition, a discussion of the implications that each has on the overall conclusions of the risk assessment is provided as a summary.

## 6.2 Uncertainties in Environmental Media Concentrations

There are several areas in the estimates of metal concentrations in environmental media (air, water, soil, backyard vegetables, diet) where uncertainties could have been introduced into the risk assessment including:

### Estimates of Dietary Intakes of Metals

Information on the levels of metals in typical foods and the daily intake of metals from the diet is limited. Reasonable data is available for nickel and several of the other metals considered in this report. However, even within these data sets there are discrepancies in the estimates of daily dietary intakes between the populations examined. For instance, estimates of daily dietary intakes of nickel by the Canadian population are two to three times the levels estimated for the US and UK populations (Appendix 4).

The Canadian data (as reported by Dabeka and McKenzie, 1995) was used in this assessment because it was felt that this provided the best reflection of likely dietary intakes for the residents of the Rodney Street community. This approach avoids under estimates of the likely dietary intake of nickel for the residents of the Rodney Street community, which in turn, ensures that upper bound estimates of total daily intakes are calculated. Similar approaches are used for the other metals considered in the detailed assessment of risk. It should be noted that this Canadian data was based upon one study conducted in the City of Montreal, and as such, may not be fully representative of the dietary habits of the Rodney Street community, or the Port Colborne population as a whole. Studies from other jurisdictions (eg., U.S. and U.K. market surveys) have shown significantly lower level of nickel intake from foods than estimated based upon the Canadian data (see Table A4-4 in Appendix 4). While some uncertainty does exist in the Canadian data, these other studies do provide confidence that the nickel intake from diet would not be underestimated in this assessment. Additionally, Dabeka and McKenzie (1995) indicated that stainless steel cooking utensils (eg., oven pan and roasting pan) appear to contribute to the higher levels of nickel in cooked steak, ground beef, port, lamb, and poultry. This may provide some rationale as to why the intake concentrations reported by Dabeka and his colleagues were higher than those presented in other jurisdictions.

**Metal Levels in Backyard Garden Produce**
The current assessment has had the benefit of more metal in backyard garden produce information than the previous assessment carried out for Port Colborne (MOE, 1998). However, even the current data only provides limited information on metal levels in a limited selection of crops. To address any uncertainties that may be introduced due to the limited nature of the present data, all available literature was considered. For the current assessment, metal levels in the examined crops were assumed to be representative of the levels found in all crops of an equivalent type. In addition, the 95th percentile of the reported levels found in the root and other vegetable categories were used to estimate exposures. This approach will over estimate likely intakes of metals. While it may be possible that future site-specific sampling may locate produce with marginally higher metal concentrations, there is sufficient conservatism built into the calculation of the soil intervention level to accommodate variability in produce metal concentrations within the Rodney Street community.

**Metal Levels in Ambient Air**
Ambient air monitoring specific to Port Colborne was available for copper, lead and nickel. The remainder of the metal levels relied on Environment Canada data for southern Ontario. While there is no reason to believe that southern Ontario data for these other metals is not representative of ambient air levels in Port Colborne, the lack of direct data introduces a level of uncertainty into the assessment. However, the detailed exposure assessment clearly showed that inhalation exposures to metals in ambient air make a very minor contribution to the total daily exposure and do not, in themselves, represent a risk. For the metals that are potential inhalation carcinogens, this uncertainty has a large impact on inhalation risk estimates.

**Metal Levels in Soil**
An extensive sampling program was undertaken in the Rodney Street community. Metal levels were assessed in over 1,300 samples. However, even with a large data set there is a potential for an error of up to 20% in the reported metal level for any one sample. To address this, the highest level of each metal was used to assess exposures for all residents of the Rodney Street community regardless of where they resided. The soil data from the properties were statistically evaluated to determine the confidence interval around the maximum value of all the samples collected from any single property. Given the large data base and the log-normal distribution of

the soil nickel levels across the Rodney Street community, the asymptotic distribution (also known as the Gumbel distribution - see Johnson and Kotz, 1995) of the maximum likelihood estimates (normal) was used to construct confidence intervals around the maximum concentration for any property. From the human health risk assessment, it was determined that at a soil nickel concentration of 9,061 µg/g, the nickel exposures from all sources including the Rodney Street community soil-specific exposure is less than the RfD for the toddler and all other age groups. Using the confidence intervals from the Gumbel distribution of the combined 2000 and 2001 Rodney Street residential soil data, it can be shown that, if the maximum soil nickel level of any single sample at any depth from a property is 8,139 µg/g or less it is 99% certain that the total nickel exposure including the Rodney Street community soil-specific exposure is less than the RfD for the toddler and all other age groups. Therefore, to ensure that no property is missed from remediation due to sample variability the soil intervention level was further lowered to 8,000 µg/g. Soil sampling and analytical variability and data confidence is discussed in Part A (sections 5.1, 5.3.5 and 5.3.6).

**Metal Levels in Indoor Dust**

Metal levels were predicted in indoor dust based on literature information comparing indoor dust levels to outdoor soil levels (section A6-5.2). It was assumed that the daily intake of soil and dust would occur from the soil and dust associated with the highest reported level of each metal. It was further assumed that this would occur throughout the year including in winter conditions when direct exposure to residential outdoor soils is limited.

It is also important to note that some data (Shorten and Hooven, 2000) has demonstrated the existence of indoor dust "reservoirs" on inaccessible surfaces within schools which have slowly accumulated based upon historical dust levels within the buildings (potentially arising from historical air emissions). Lead dust concentrations were significantly elevated on the inaccessible surfaces (tops of filing cabinets and light fixtures) yet they were uniformly low on accessible surfaces (desktops and windowsills) and the children's palms. Lead in the inaccessible surfaces had no effect on blood lead levels in the children over a six month period indicating that the mere presence of lead in inaccessible dust does not automatically constitute a health hazard.. If indoor dust reservoirs are not disturbed (ie., extensive renovations), one would not expect indoor dust concentrations to be significantly elevated. Although events such as renovations may result in an elevation of ambient metal concentrations in indoor air and dust, these exposures would be of a very short term nature and expected to occur infrequently. Further investigations are currently underway in the Port Colborne region which should provide a more detailed data set to evaluate the relative contribution of indoor dust "reservoirs" to metal exposures.

**Estimates of Metal Bio-accessibility from Soil**

The metals in the soil, particularly nickel, are largely present in insoluble forms that are tightly bound to the soil matrix. Therefore their accessibility to the body, either in the gut, or through the skin, will depend upon their release from the soil. While the metals are insoluble in water at neutral pH (6 - 8), their solubility increases under acidic conditions. To address the potential for metal release from the soil during digestion, soils were subjected to both a simulated stomach acid leach test and bioaccessibility testing (Appendix 5).

There is also some uncertainty with respect to the relative bioavailabilities of metals in outdoor soils *versus* those present with indoor dust. Indoor dust is typically composed of much finer-sized particulate than that found in the outdoor ambient environment. While very little data is available to determine differences in relative bioavailabilities, one study on arsenic concentrations administered to Cynomolgus monkeys indicated that the oral bioavailability of metals in indoor dust was slightly higher than that present in outdoor soils (Freeman et al., 1995).

### 6.3 Uncertainties in Receptor Characteristics

There are several areas related to the characteristics and activity patterns of the residents where uncertainties can be introduced into the assessment of exposure and risk.

**Receptor Characteristics**
As noted above, the use of single point values to characterize the population does not account for the wide variation that exists within any community. The receptor parameters used in this assessment have been taken from Canadian sources and are based on statistical surveys of the Canadian population. As such, they can be considered to be reasonably representative of the residents of the Rodney Street community.

Statistical methods exist to address these variations and provide ranges of exposures and risk for a community. However, these techniques are really only beneficial when an initial worst case assessment demonstrates that potential risks exist. The current assessment made use of conservative assumptions to provide reasonable upper bound estimates of exposure and risk. These showed that even at the highest predicted exposures for antimony, beryllium, cadmium, cobalt and copper, risks do not exist within the community. Therefore a refinement of exposure estimates to account for variation within the population was not deemed necessary.

**Activity Patterns**
The current assessment assumed that a person would be living in the Rodney Street community for a full 70 year life-time. All exposures were assumed to occur within this community. Correction was made for time spent away for this area. This approach will provide an upper-bound estimate of potential exposures from the site.

**Dermal Contact with Soil**
Dermal contact for metals is generally considered to be a very minimal pathway of exposure. However, in the current assessment, dermal exposure was estimated to ensure that this contribution to the total daily exposure was examined.

**Consumption of Home Grown Produce**
There is some uncertainty associated with the actual amount of home grown produce a family could consume. For the current assessment, it was conservatively assumed that a family of four would consume 100% of the total garden yield. In addition to this assumption, annual backyard garden yields were based on an assumed garden size and an estimated average crop yield. Depending on the actual family size, garden size, and crop yield, this may be an over or under-estimate of individual exposure. However, given that there was no reduction of exposures to home garden produce due to crop loss (eg., browsing by wildlife and birds or spoilage), it is concluded that the estimates employed in this assessment would be conservative.

This assumption results in a calculated home grown produce consumption rate which represent approximately 9.9% of the total produce (ie., both home grown and store bought produce) consumed by the Rodney Street residents, in addition to the 100% food consumption assumed from market basket produce. It should also be noted that very few of the residences in the Rodney Street area have home gardens. However, this pathway has been considered in all cases to ensure that the assessment is sufficiently conservative as to enable any resident to grow and consume home garden produce without any health risk based upon soil metal concentrations.

## 6.4 Uncertainties in Toxicity Assessment

### Non-Cancer Endpoints

Each of the toxicologically based exposure limits used to estimate potential health risks related to non-cancer endpoints have uncertainty factors associated with them. These factors account for the strength of the toxicological data and incorporate uncertainty factors to account for intraspecies and interspecies extrapolations of toxicological data. These uncertainty factors reflect the adequacy of the toxicological data available for each compound. Where toxicological data is poor or limited to one or two studies, large uncertainty factors are applied to ensure adequate protection of sensitive members of the population. The result is a general over-estimation of potential risks from exposure. Thus, exposures which exceed the exposure limits may not always result in adverse health effects. The uncertainty factor attached to each exposure estimate gives a measure of this potential. The lower the uncertainty factor, the more certain the data and the more predictive of adverse health effects an exposure limit is. In these cases, the probability that exceedances of exposure limits will result in adverse health effects is higher. For exposure limits with higher uncertainty factors, the probability of adverse effects occurring as a result of limited exceedance of exposure limits is thought to decline. A more detailed discussion of uncertainty factors and their derivation is provided in Section 1 of Appendix A2.

The toxicity and exposure limits selected in this study also have conservative assumptions incorporated into them. However, since these parts of the risk assessment were taken from the reviewed literature and from recognized regulatory agencies, discussion of their uncertainty is beyond the scope of this report. However, it should be noted that the toxicological basis of exposure limits is updated as new information becomes available so every effort was made to ensure that recent information was used.

The US EPA is a reliable source of exposure limits or reference doses (R*f*D) for ingestion exposures and reference concentration (R*f*C) for inhalation exposures, that are developed from toxicological studies of human or animal populations. These are set to ensure that chronic exposures to a chemical at concentrations that are at or below the exposure limit will not result in adverse effects. The US EPA (US EPA IRIS, 1998a-e)defines the R*f*D/R*f*C as;

> *A quantitative estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of non-carcinogenic, deleterious effects during a life-time.*

There may be uncertainty as to whether the current US EPA R*f*D of 20 µg nickel/kg-day (US EPA IRIS, 1998e - oral R*f*D assessment last revised 1996) completely protects against the contact dermatitis experienced by a percentage of the population, mainly female, who are already sensitized to nickel through wearing jewelry, dental or surgical prostheses or other contact with metallic nickel and stainless steel.

**Cancer Endpoints**

Derivation of exposure limits for cancer endpoints usually involves extrapolating from animal data to humans and from high doses (the doses which cause measurable effects in animals) to low doses (where there will be no effect in humans). More recently, where there is better information on human exposure, epidemiological information can be used to extrapolate to human risks removing the animal to man extrapolation uncertainty.

Carcinogens are assumed to have no threshold for their effects. This is related to the early studies of the effects of ionizing radiation on human cancer. In fact, carcinogenic chemicals were once called "radio-mimetic" compounds. Because of the mathematical relationships between radiation exposure and human cancers, similar mathematical models have been used to extrapolate from animal cancer bioassay studies to levels where the risk of exposure is negligible in a large population ($10^{-5}$ to $10^{-6}$ risk level). These mathematical models are extremely conservative and make several assumptions which may not hold true for the behaviour of chemicals in the body. Some of these assumptions introduce uncertainty into the mathematical extrapolation:

- the no-threshold assumption, ie., that a single molecule can cause an event leading to cancer development. Carcinogenesis is a multistep process with three generally recognized processes, namely, initiation, promotion and progression. It is also known that non-genetic processes can trigger or control gene expression and that specific genes are involved in various cancers. Chemical theory and behaviour of biological systems suggests that a sufficient population of molecules must be present to trigger an event such as initiation and also to promote the subsequent stages of carcinogenesis. Consequently, in some cases, a "practical" or operational threshold concentration may be involved;

- the genotoxicity assumption - mathematical models assume that direct action on the genetic material is involved. Several carcinogens are indirect in that they cause cancer without causing direct damage to genetic material. The "standard" mathematical models do not account for this;

- the mathematical models extrapolate several orders of magnitude from the realm of measured effects (high dose) in biological systems to a range where nothing can be verified biologically.

For these reasons, likelihood estimates are used for carcinogens with a range of risks over which some description of whether the impact is negligible or not can be assigned.

Human epidemiological studies have many limitations related to proving that there is a causal association between chemical exposure and effects in the population, ie., the healthy worker effect, mis-classification of workers, confounding variables, such as smoking, latency period, the fact that associations can only be used for populations not individuals, and other difficulties in showing dose-response relationships.

**Extrapolation from Occupational Air Data**

The uncertainties associated with extrapolating from the occupational air sampling data used to estimate lung cancer risk in nickel refinery workers (section A2-9.3.1) to potential lung cancer risks due to current levels of airborne nickel in Port Colborne are described in section A2-9.2.1.1. A comparison of the particle size distributions, masses and speciation of nickel compounds in occupational settings and ambient air and the sampling methodology available to sample airborne nickel indicates that TSP-based measurements can be compared with the older "total" personal air sampling data from the nickel refinery workers for estimating potential lung cancer risk associated with breathing Port Colborne air. The use of $PM_{10}$ and $PM_{2.5}$ data introduces more uncertainty and a requirement to prorate older workplace exposure data so that "respirable" fractions are comparable.

## 6.5 Uncertainties in the Risk Characterization

### Using an Exposure Limit for Nickel Soluble Salts

In estimating potential risks associated with ingestion and dermal exposures to nickel, the report made use of the non-cancer oral exposure limit for soluble nickel salts put forward by the US EPA (US EPA IRIS, 1998e - oral RfD assessment last revised 1996) and the Institute of Medicine (IOM, 2001). The nickel in soil in the Rodney Street community has been identified predominantly as nickel oxide which is insoluble in water. Therefore there are some potential uncertainties associated with using an oral exposure limit set for a soluble form of the metal. However, the risk assessment made use of both a stomach acid leach test and bioaccessibility testing to determine the amount of nickel that could be released from the soil matrix during digestion. This digestion would, in fact convert nickel oxide to soluble forms. Once released from the soil matrix, the nickel would be in the form of a soluble salt. Thus, the comparison of this acid soluble fraction of soil nickel to an exposure limit set for a soluble form of nickel is appropriate.

### Use of Life-Time Chronic Daily Intakes (CDI)

The current assessment developed life-time chronic daily intakes (CDI) estimates from all age groups (life stages) to estimate the life-time exposure. These values were compared to the reference dose limits set by the US EPA. This is the approach recommended by the US EPA. The use of a life-time CDI is appropriate for the current assessment because exposures have been considered to occur nearly every day over a 70 year life-time, a truly life-time exposure.

Estimates of exposure for individual age groups have also been compared to the reference dose. If exposures for individual age groups exceed the reference dose then, as in the case of nickel exposure to the preschool toddler, a soil intervention level was established. However, the likelihood that life-time exposures will result in adverse effects is limited. This approach is conservative.

## 6.6 Implications of Uncertainties

### Systemic Health Effects

There are a number of areas where uncertainties may have been introduced into the current assessment of exposure and risk. Throughout, conservative assumptions have been used in an effort to provide estimates of the reasonable upper bound exposures. The objective was to determine if these exposures had the potential to cause adverse health effects in the residents of the Rodney Street community. The risk characterization has shown that even under the conservative conditions that have been assumed to exist in the Rodney Street community, exposures to metals in the soil in the community would not be expected to result in adverse health effects. In most cases, the estimated exposures were significantly lower than the exposure limits identified for each metal.

**Contact Dermatitis**

The current assessment for nickel shows that the risks of systemic effects occurring as a result of exposure to nickel in the soil are limited. However, the potential for contact dermatitis to occur in response to skin contact with soil, or through the ingestion of nickel bearing soil in individuals who have already been sensitized to nickel has not been addressed. In the absence of exposure limits set to protect against this effect, the risk assessment process employed here cannot effectively address this issue. A more complete discussion of contact dermatitis can be found in Appendix 2 (section A2-9.2.4).

## 7.0 Recommendations and Conclusions

A reasonable upper bound exposure estimate was modeled using the maximum reported metal levels or other upper-bound estimates in surface soil within the Rodney Street community, in municipal drinking water, in backyard produce from the Rodney Street community, in supermarket food and in air monitoring data for Port Colborne or for nine other sites in Ontario. The exposure assessment looked at receptors for each age class (infant, toddler, child, teen and adult) and modeled exposures for inhalation, ingestion and dermal contact using standard exposure assessment methodologies. Adjustments were made for the fact that the predominant form of nickel in the Rodney Street community is insoluble nickel oxide. Acid leachate tests and bioaccessiblity studies were used to adjust for the amount of each metal that would be bioaccessible in the digestive tract. A dermal uptake factor for nickel was developed based on several published studies of nickel permeation of human skin. In other cases, accepted dermal exposure factors were taken from the scientific literature.

Metal exposures for residents of the Rodney Street community were divided into two main components, those related either to dermal contact with metals in the soil or the ingestion of soil and/or backyard garden produce from the Rodney Street community, and general exposures to metals such as those experienced by people elsewhere in Ontario. These general exposures include supermarket food, municipal drinking water and ambient air. The major contributor, in all cases, to total daily intakes of metals is supermarket food which is independent of any local soil metal exposures experienced in the Rodney Street community.

When total metal exposures are broken down by age group, the highest exposures are for the infant and toddler age classes (up to five years old). Reasonable upper bound exposures for these age classes only exceeded the US EPA R*f*D for nickel.

Potential health risks from inhaling airborne metals were assessed by comparing either the highest or mean annual average air concentration in the MOE air monitoring data for Port Colborne or Environment Canada air monitoring data for Ontario (Table A3-3) with the selected inhalation exposure limit (R*f*C, unit cancer risk, etc.). In all cases, there appears to be little or no potential for health related effects from inhalation of these metals in ambient air in the Rodney Street community.

Exposures to lead and arsenic were assessed by comparison with health studies of other Ontario communities with elevated soil concentrations of these metals that were generally higher than those in the Rodney Street community. Conclusions and recommendations for arsenic and lead are described in separate sections below.

### 7.1 Nickel

The total chronic daily intake for people exposed to soil containing 17,000 µg/g nickel for their entire life-time is about 50% of the US EPA R*f*D. For the infant age class, total nickel intakes from the some assumed diets exceed the US EPA R*f*D; however, consideration of more reasonable infant diets indicate that at 17,000 µg/g it is unlikely that the infant's exposure exceeds the established exposure limit. At the maximum soil nickel concentration in the Rodney Street community (17,000 µg/g), the toddler receptor exceeds the R*f*D level of exposure. Additionally, the following should be noted:

1. The health benchmark used is the US EPA (IRIS) (1998e - oral R*f*D assessment last revised 1996) and Institute of Medicine (2001) R*f*D for soluble nickel salts. This R*f*D is for life-time protection and the endpoints of concern are reduced organ weight and reproductive endpoints found in animal studies.

2. It is generally assumed by most authorities that the R*f*D given in terms of µg / kg body weight /day is valid for children as well as for adults, while recommending that the exposure of infants and children to contaminants be kept as low as practicable. Although it is generally recognized that children may be more susceptible to the effects of contaminants than adults, the evidence often comes from differences in exposure rather than from animal studies. All major regulatory agencies (Health Canada, U.S. EPA, OECD/WHO) have placed a high priority on protecting children's environmental health. Currently, there are no standard national or international regulatory approaches for developing criteria to protect sensitive groups, such as children, although research is now underway in this area.

   For nickel, the most exposed life-stage is the toddler age group and as such it is considered prudent, in this case, to establish a soil intervention level that does not exceed the R*f*D for this group. Consideration of the lifetime CDI for total nickel exposures, including Rodney Street community specific exposures, indicates that by setting a soil intervention level to protect the toddler aged group, that the R*f*D would not be exceeded by older age groups.

3. At the present time, evidence of actual harm from exposure to soils containing elevated levels of nickel in the Rodney Street community is being assessed by a separate ongoing health study.

4. There are no similar assessments of other communities with similar or higher levels of nickel exposure.

At a concentration of 9,061 µg/g nickel in the soil, the total exposure to nickel from general and Rodney Street soil specific exposures is equivalent to the R*f*D for the toddler. Under the 'reasonable' diet scenarios, the infants exposure is less that the RfD as well. All the age groups do not exceed the US EPA RfD at this level.

Part A Section 5.3.6 identified the soil samples collected in the Rodney Street community had variability. To ensure there is a high level of confidence that no property is missed from remediation due to sample variability the soil intervention level is lowered to 8,000 µg nickel/g soil.

This site specific soil intervention level of 8,000 µg nickel/g soil was developed specifically for the Rodney Street community. The available scientific data on nickel dermal sensitization are inadequate to determine a soil intervention level that would be protective to nickel dermatitis in sensitized individuals, or that would protect people from being sensitized to nickel. However, ongoing research studies in the Port Colborne community will be testing people for nickel contact dermatitis over the next eight to ten months, which should provide additional data to allow for better characterization of this information gap.

In the case of inhaled nickel, the three estimated life-time cancer risks were in the $10^{-5}$ life-time risk range. These estimates were based on unit inhalation risk factors developed for nickel refinery dusts. This risk range is considered very low. Inspection of the annual average air concentration of nickel based on TSP sampling in 1995 and the recent TSP air sampling data at the Rodney Street location (summer 2001) indicate that there has been a continuing downward trend in airborne nickel since the 1992 to 1995 period, such that the actual cancer risk for inhaling ambient air in the Rodney Street community may be less than $10^{-5}$ life-time risk. The Ministry will continue to monitor ambient air concentrations in the Port Colborne community.

Because the link between soil levels and ambient air concentrations cannot be reliably estimated, the cancer risk from inhalation exposure was appropriately not used to derive the soil intervention level.

### 7.1.1 Recommendations for Nickel

1. The site specific soil intervention level of 8,000 µg nickel/g for non-cancer effects developed specifically for the Rodney Street community, be used to facilitate remediation of affected properties in the Rodney Street community.

## 7.2 Arsenic

It is concluded that the measured levels of arsenic in these soils are unlikely to pose an undue health risk to residents of this community based upon consideration of:

1. Comparison to typical levels elsewhere.
2. Knowledge of outcomes of health studies involving arsenic in soil exposure in other Ontario communities.

### 7.2.1 Recommendations for Arsenic

1. Residents living on properties with arsenic levels above the MOE guideline should be

provided with the MOE Greenfact Sheet entitled, "Arsenic in the Environment" which outlines simple measures related to reducing exposure.

### 7.3 Lead

The weight of evidence would support an intervention level for exposure reduction of 1,000 µg/g in soils based on:

1. Empirical findings regarding the potential contribution of soil lead levels to blood lead in children and a blood lead level of concern of 10 µg/dL.
2. Use of the US EPA Biokinetic model suggest that 1,000 µg/g would provide adequate protection with a margin of safety.
3. The new EPA lead in soil standard of 1,200 µg/g suggests that an intervention level of 1,000 µg/g lead in soil would be protective of persons in this community.
4. Abatement observations that suggest that only remediation of soils in excess of 1,000 µg/g have a measurable impact on exposure reduction.

In addition, adoption of the US EPA stratified approach to a soil standard seems desirable to focus resources and efforts on those areas which have the highest exposure potential for children. Therefore, an intervention level of 400 µg/g for lead in bare soil play areas is reasonable to apply. Bare soil allows for greater contact of soil particles with children and therefore a more stringent value than 1,000 µg/g is warranted for these specific areas on a property.

#### 7.3.1 Recommendations for Lead

1. An intervention level be established for this community at a soil lead level of 400 µg/g for children's play areas with bare soil on residential properties or in public areas, and at a level of 1,000 µg/g for all other areas of these properties to which children have access.
2. Soil removal, where conducted, should take into account the depth of the contamination. Wet methods of dust control should be employed.
3. Residents living at properties exceeding these intervention levels for lead in soil should minimize/avoid contact with these soils and not consume vegetables from backyard gardens.
4. All households with measured lead levels above the Ministry screening guideline (200 µg/g) receive the MOE fact sheet on "Lead in Soil" to provide a better understanding of lead exposure and simple measures that can reduce potential exposure.

### 7.4 Antimony, Beryllium, Cadmium, Cobalt and Copper

For the metals, antimony, beryllium, cadmium, cobalt and copper, estimated total daily intakes for all age classes were well below stringent oral or inhalation exposure limits from major recognized jurisdictions, such as, the US EPA, WHO and Health Canada.

No soil intervention levels for the metals, antimony, beryllium, cadmium, cobalt and copper, in soil in the Rodney Street community are recommended.

## 8.0 References

The references listed here pertain to the citations contained in this, the main document. Lists of the references used in each of the appendices are provided at the end of each appendix.

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# Appendix 1

# Environmental Monitoring of Metals in Rodney Street and Port Colborne

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## Drinking Water Monitoring Data

### Table A1-1: Summary of Port Colborne Municipal Drinking Water Data, 1996 -1999 (Number of Samples = 8)

| Element | Range of Drinking Water Concentrations (µg/L) | Average Drinking Water Concentrations (µg/L) | MOE Drinking Water Standard (µg/L) | World Health Organization Drinking Water Guidelines (µg/L) | EPA Maximum Contaminant Levels (µg/L) |
|---|---|---|---|---|---|
| ***Treated Drinking Water*** | | | | | |
| Antimony | 0.31 - 0.96 | 0.60 | none | 5 (provisional) | 6 |
| Arsenic | 0.2 - 0.6 | 0.34 | 25 | 10 (provisional) | 5 |
| Beryllium | 0.11 - 0.2 | 0.16 | none | none | 4 |
| Cadmium | 0.0041 - 0.051 | 0.02 | 5 | 3 | 5 |
| Cobalt | 0.025 - 0.054 | 0.03 | none | none | none |
| Copper | 0.33 - 1 | 0.65 | none | 2,000 (provisional) | 1,300 (aesthetics) |
| Lead | 0.05 - 1.9 | 0.37 | 10 | 10 | 15 |
| Nickel | 0.4 - 1.1 | 0.77 | none | 20 (provisional) | none |
| ***Distributed Water at Charlotte Street*** | | | | | |
| Antimony | 0.45 - 0.97 | 0.64 | none | 5 (provisional) | 6 |
| Arsenic | 0.14 - 0.40 | 0.28 | 25 | 10 (provisional) | 5 |
| Beryllium | 0.03 - 0.2 | 0.11 | none | none | 4 |
| Cadmium | 0.022 - 0.083 | 0.06 | 5 | 3 | 5 |
| Cobalt | 0.026 - 0.04 | 0.03 | none | none | none |
| Copper | 5 - 44.1 | 14.50 | none | 2,000 (provisional) | 1,300 (aesthetics) |
| Lead | 0.067 - 0.71 | 0.38 | 10 | 10 | 15 |
| Nickel | 0.6 - 1.3 | 0.94 | none | 20 (provisional) | none |

* EPA Region III Risk Based Concentrations are not standards or guidelines and were used for comparison purpose only when the MOE or EPA did not have a standard/guideline for a particular substance.

## Air Monitoring Data

### Table A1-2a: MOE TSP Nickel Annual Air Monitoring Data (1992-1995) from Monitoring Station 27047 at Davis and Fraser and Summer 2001 Monitoring at Rodney Street (µg/m$^3$)

| Year (# of Samples) | Percentiles | | | | | | Maximum µg/m$^3$ | Mean µg/m$^3$ | Geom. Mean µg/m$^3$ |
|---|---|---|---|---|---|---|---|---|---|
| | 10% | 30% | 50% | 70% | 90% | 99% | | | |
| 1992 (54) | 0.005 | 0.005 | 0.020 | 0.038 | 0.130 | 0.496 | 0.690 | 0.053 | 0.020 |
| 1993 (49) | 0.002 | 0.006 | 0.010 | 0.020 | 0.090 | 0.302 | 0.390 | 0.034 | 0.013 |
| 1994 (48) | 0.004 | 0.007 | 0.011 | 0.021 | 0.067 | 0.141 | 0.160 | 0.025 | 0.014 |
| 1995 (55) | 0.003 | 0.008 | 0.011 | 0.019 | 0.049 | 0.135 | 0.140 | 0.023 | 0.011 |
| 2001 (22) | INS | INS | INS | INS | INS | INS | 0.12 | 0.013 | INS |

INS = insufficient data

### Table A1-2b: Comparison of $PM_{10}$ Nickel-In-Air Concentrations in Port Colborne With Other Areas in Southern Ontario Based on the Most Recently Available Results

| Location | Start | End | Number of Samples | Number Below Detection Limit | Mean µg/m$^3$ | Maximum µg/m$^3$ | Minimum µg/m$^3$ |
|---|---|---|---|---|---|---|---|
| Ottawa | 03-Jan-95 | 25-Dec-98 | 217 | 104 | 0.0030 | 0.0351 | 0.0008 |
| Point Petre | 25-Aug-96 | 31-Dec-98 | 117 | 64 | 0.0018 | 0.0068 | 0.0009 |
| Windsor | 03-Jan-95 | 31-Dec-98 | 181 | 38 | 0.0043 | 0.0226 | 0.0010 |
| Toronto | 03-Jan-95 | 06-Sep-95 | 37 | 10 | 0.0036 | 0.0088 | 0.0010 |
| Toronto | 21-Feb-97 | 31-Dec-98 | 93 | 25 | 0.0030 | 0.0084 | 0.0009 |
| Toronto | 02-Jun-95 | 31-Dec-98 | 179 | 27 | 0.0041 | 0.0109 | 0.0010 |
| Hamilton | 03-Jan-95 | 25-Dec-98 | 193 | 45 | 0.0034 | 0.0133 | 0.0007 |
| Walpole Island | 03-Jan-95 | 04-Mar-95 | 8 | 4 | 0.0018 | 0.0036 | 0.0010 |
| Egbert | 10-Mar-95 | 31-Dec-98 | 179 | 93 | 0.0023 | 0.0109 | 0.0009 |
| Port Colborne | Summer 2001 | | 21 | 9 | 0.0059 | 0.0260 | 0.0010[*] |

[*] The minimum value for nickel-in-air represents ½ detection limit and was used in the calculation of the average value.

## Table A1-3: Summary of Annual Air Monitoring Data for Port Colborne

| Metal | Minimum Air Concentration (µg/m³) | Maximum Air Concentration (µg/m³) | Average Air Concentration (µg/m³) | MOE Air Standard (24 hour) |
|---|---|---|---|---|
| ***Ministry of the Environment - Davis and Fraser, Port Colborne Air Monitoring Data - 1992 - 1995*** | | | | |
| Copper (TSP) | 0.058 | 0.56 | 0.112 | 50 |
| Lead (TSP) | 0.01 | 0.06 | 0.02 | 2 |
| Total Suspended Particulate | 9 | 222 | 51.7 | 120 |
| ***Ministry of the Environment - Rodney Street, Port Colborne Air Monitoring Data - Summer 2001*** | | | | |
| Cadmium (TSP) | ND | 0.3 | 0.046 | 2 |
| Cadmium ($PM_{10}$) | 0.0001 | 0.0005 | 0.0002 | NA |
| Total Suspended Particulate | 24 | 100 | 51.8 | 100 |
| $PM_{10}$ | 12 | 66 | 22.8 | 50 |
| ***Jacques Whitford Environmental - Air Monitoring Data for Port Colborne Schools - Summer 2000*** | | | | |
| Arsenic (TSP) | 0.001 | 0.005 | 0.002 | 0.3 |
| Cobalt (TSP) | 0.004 | 0.01 | 0.0075 | 0.1 |
| Copper (TSP) | 0.01 | 0.08 | 0.035 | 50 |
| Nickel (TSP) | 0.01 | 0.11 | 0.05 | 2 |
| Total Suspended Particulate | 24 | 63 | 48.7 | 120 |
| $PM_{10}$ | 21 | 44 | 34 | 50 |
| ***Environment Canada Air Monitoring Program - Typical Ontario Air Concentrations - 1995 - 1999*** | | | | |
| Antimony ($PM_{10}$) | 0.0001 | 0.0115 | 0.0011 | 25 |
| Arsenic ($PM_{10}$) | 0.003 | 0.016 | 0.0016 | 0.3 |
| Beryllium ($PM_{10}$) | No data available | | | 0.01 |
| Cadmium ($PM_{10}$) | 0.0001 | 0.0067 | 0.0007 | 2 |
| Cobalt ($PM_{10}$) | 0.001 | 0.017 | 0.002 | 0.1 |
| Copper ($PM_{10}$) | 0.001 | 0.101 | 0.018 | 50 |
| Lead ($PM_{10}$) | 0.0005 | 0.13 | 0.0077 | 2 |
| Nickel ($PM_{10}$) | 0.0007 | 0.035 | 0.003 | 2 |

## Soil Monitoring Data

### Table A1-4: Summary of Soil Data (All Depths Combined)

| Element | Concentration (µg/g) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | Median | 10th Percentile | 20th Percentile | 30th Percentile | 40th Percentile | 50th Percentile | 60th Percentile | 70th Percentile | 80th Percentile | 90th Percentile |
| Aluminum | 3200 | 47300 | 17850 | 17800 | 8990 | 12000 | 14100 | 16000 | 17800 | 19500 | 20920 | 22900 | 26600 |
| Antimony | 0.28 | 91 | 1.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.8 | 1.4 | 3.1 |
| Arsenic | 0.3 | 350 | 15.9 | 12.7 | 5.7 | 7.5 | 8.7 | 10.5 | 12.7 | 15 | 17.8 | 21.3 | 29 |
| Barium | 19 | 956 | 173 | 157 | 90 | 109 | 127 | 142 | 157 | 174 | 191 | 217 | 270 |
| Beryllium | 0.2 | 4.6 | 1 | 1 | 0.6 | 0.7 | 0.8 | 0.9 | 1 | 1.1 | 1.2 | 1.3 | 1.4 |
| Cadmium | 0.1 | 35 | 1.2 | 1.1 | 0.4 | 0.6 | 0.78 | 0.93 | 1.09 | 1.25 | 1.47 | 1.74 | 2.16 |
| Calcium | 1920 | 93400 | 20100 | 18700 | 10300 | 13200 | 15000 | 16700 | 18700 | 20900 | 23300 | 25600 | 30540 |
| Chromium | 6 | 245 | 30 | 29 | 20 | 23 | 26 | 28 | 29 | 31 | 34 | 36 | 40 |
| Cobalt | 3.5 | 262 | 51 | 40 | 20 | 25 | 30 | 34 | 40 | 47 | 55 | 70 | 91 |
| Copper | 4.4 | 2720 | 250 | 200 | 73 | 109 | 137 | 164 | 200 | 237 | 290 | 367 | 471 |
| Iron | 8820 | 130000 | 29500 | 27300 | 18480 | 21200 | 23500 | 25700 | 27300 | 29700 | 32100 | 35700 | 42280 |
| Lead | 5.9 | 1800 | 222 | 179 | 77 | 99 | 122 | 151 | 179 | 208 | 249 | 302 | 406 |
| Magnesium | 990 | 31900 | 7780 | 7220 | 4376 | 5544 | 6190 | 6650 | 7220 | 7916 | 8720 | 9828 | 11530 |
| Manganese | 131 | 5620 | 506 | 480 | 344 | 392 | 430 | 459 | 480 | 501 | 540 | 588 | 664 |
| Molybdenum | 0.2 | 12 | 4 | 4 | 1 | 2 | 3 | 4 | 4 | 4 | 5 | 5 | 6 |
| Nickel | 35 | 17000 | 2544 | 1800 | 543 | 808 | 1090 | 1414 | 1800 | 2280 | 2880 | 3900 | 5588 |
| Strontium | 14 | 690 | 79 | 69 | 39 | 49 | 56 | 63 | 69 | 78 | 88 | 100 | 123 |
| Vanadium | 11 | 75 | 37 | 37 | 25 | 29 | 32 | 35 | 37 | 40 | 42 | 45 | 50 |
| Zinc | 23 | 1750 | 369 | 314 | 146 | 190 | 227 | 266 | 314 | 363 | 428 | 522 | 561 |
| Selenium | 0.1 | 19.4 | 1.29 | 0.29 | 0.15 | 0.15 | 0.15 | 0.15 | 0.29 | 0.68 | 1.26 | 2.4 | 4.1 |

Data are µg/g dry weight.
Soil Samples from 2000 Soil Sampling Investigation.

## Backyard Garden Produce Monitoring Data

### Table A1-5: Levels of Antimony in Produce from Rodney Street Residences

| Location | Antimony Soil Concentration (µg/g) | Produce Type | Dry Weight Antimony Concentration in Produce (µg/g) | Conversion Factor (Dry to Fresh Weight) | Fresh Weight Antimony Concentration in Produce (µg/g) |
|---|---|---|---|---|---|
| JWEL 2000 Samples | | | | | |
| 3 | <0.5 | Beet Root | 0.06 | 0.13 | 0.0078 |
| | | Celery | <0.05 | 0.059 | - |
| | | Tomato | <0.1 | 0.065 | - |
| 9 | Not analyzed | Tomato | <0.1 | 0.065 | - |
| 25 | 1.1 | Pepper | <0.1 | 0.066 | - |
| | | Lettuce | 0.46 | 0.045 | 0.021 |
| | | Beet Root | <0.1 | 0.13 | - |
| 33 | Not analyzed | Lettuce | <0.1 | 0.045 | - |
| | | Pepper | <0.05 | 0.066 | - |
| 34 | Not analyzed | Radish | <0.05 | 0.055 | - |
| | | Pepper | 0.27 | 0.066 | 0.018 |
| 41 | Not analyzed | Tomato | <0.1 | 0.065 | - |
| Control Samples | | | | | |
| Food Store Control | n/a | Beet | <0.05 | 0.13 | - |
| | | Pepper | <0.1 | 0.066 | - |
| | | Lettuce | <0.15 | 0.045 | - |
| Wainfleet Bog (Background Control) | n/a | Beet Root | <0.05 | 0.13 | - |
| | | Pepper | <0.1 | 0.066 | 0.0066 |
| | | Beet Top | <0.1 | 0.091 | - |

n/a - not available.

## Table A1-6: Levels of Beryllium in Produce from Rodney Street Residences

| Location | Beryllium Soil Concentration (µg/g) | Produce Type | Dry Weight Beryllium Concentration in Produce (µg/g) | Conversion Factor (Dry Weight to Fresh Weight) | Fresh Weight Beryllium Concentration in Produce (µg/g) |
|---|---|---|---|---|---|
| JWEL 2000 Samples | | | | | |
| 3 | 0.7 | Beet Root | <0.1 | 0.13 | 0.0065 |
| | | Celery | <0.1 | 0.059 | 0.00295 |
| | | Tomato | <0.1 | 0.065 | 0.00325 |
| 9 | Not Analyzed | Tomato | <0.2 | 0.065 | 0.0065 |
| 25 | 0.5 | Pepper | <0.2 | 0.066 | 0.0066 |
| | | Lettuce | <0.2 | 0.045 | 0.0045 |
| | | Beet Root | <0.1 | 0.13 | 0.0065 |
| 33 | Not Analyzed | Lettuce | <0.2 | 0.045 | 0.0045 |
| | | Pepper | <0.1 | 0.066 | 0.0033 |
| 34 | Not Analyzed | Radish | <0.1 | 0.055 | 0.00275 |
| | | Pepper | <0.3 | 0.066 | 0.0099 |
| 41 | Not Analyzed | Tomato | <0.2 | 0.065 | 0.0065 |
| MOE Samples | | | | | |
| Sample #1 | 0.75 | Tomato | 0.1 | 0.065 | 0.0065 |
| | | Green Pepper | 0.1 | 0.066 | 0.0066 |
| Sample #2 | 0.425 | Pepper | 0.1 | 0.066 | 0.0066 |
| | | Tomato | 0.1 | 0.065 | 0.0065 |
| Control Samples | | | | | |
| Food Store Control | n/a | Beet | <0.1 | 0.13 | 0.0065 |
| | | Pepper | <0.2 | 0.066 | 0.0066 |
| | | Lettuce | <0.3 | 0.045 | 0.00675 |
| Wainfleet Bog (Background Control) | 0.5 | Beet Root | <0.1 | 0.13 | 0.0065 |
| | | Pepper | <0.2 | 0.066 | 0.0066 |
| | | Beet Top | <0.2 | 0.091 | 0.0091 |

* One half the detection limit used for values reported as <detection limit.

n/a - not available.

## Table A1-7: Levels of Cadmium in Produce from Rodney Street Residences

| Location | Cadmium Soil Concentration (µg/g) | Produce Type | Dry Weight Cadmium Concentration in Produce (µg/g) | Conversion Factor (Dry Weight to Fresh Weight) | Fresh Weight Cadmium Concentration in Produce (µg/g) |
|---|---|---|---|---|---|
| JWEL 2000 Samples | | | | | |
| 3 | <0.5 | Beet Root | 0.38 | 0.13 | 0.049 |
| | | Celery | 0.85 | 0.059 | 0.05 |
| | | Tomato | 0.23 | 0.065 | 0.015 |
| 9 | Not Analyzed | Tomato | 0.13 | 0.065 | 0.0085 |
| 25 | 1.1 | Pepper | 0.15 | 0.066 | 0.0099 |
| | | Lettuce | 0.34 | 0.045 | 0.015 |
| | | Beet Root | 0.24 | 0.13 | 0.031 |
| 33 | Not Analyzed | Lettuce | 0.45 | 0.045 | 0.02 |
| | | Pepper | 0.22 | 0.066 | 0.015 |
| 34 | Not Analyzed | Radish | 0.16 | 0.055 | 0.0088 |
| | | Pepper | 0.28 | 0.066 | 0.018 |
| 41 | Not Analyzed | Tomato | 0.13 | 0.065 | 0.0085 |
| MOE Samples | | | | | |
| Sample #1 | 0.8 | Tomato | 0.2 | 0.065 | 0.013 |
| | | Green Pepper | 0.05 | 0.066 | 0.0033 |
| Sample #2 | 0.1 | Pepper | 0.2 | 0.066 | 0.013 |
| | | Tomato | 0.2 | 0.065 | 0.013 |
| Control Samples | | | | | |
| Food Store Control | n/a | Beet | 0.21 | 0.13 | 0.027 |
| | | Pepper | 0.17 | 0.066 | 0.011 |
| | | Lettuce | 1.06 | 0.045 | 0.048 |
| Wainfleet Bog (Background Control) | 0.3 - 0.4 | Beet Root | 0.31 | 0.13 | 0.04 |
| | | Pepper | 0.89 | 0.066 | 0.059 |
| | | Beet Top | 0.69 | 0.091 | 0.063 |

n/a - not available.

## Table A1-8: Levels of Cobalt in Produce from Rodney Street Residences

| Location | Cobalt Soil Concentration (µg/g) | Produce Type | Dry Weight Cobalt Concentration in Produce (µg/g) | Conversion Factor (Dry Weight to Fresh Weight) | Fresh Weight Cobalt Concentration in Produce (µg/g) |
|---|---|---|---|---|---|
| JWEL 2000 Samples | | | | | |
| 3 | 20.1 | Beet Root | 0.37 | 0.13 | 0.048 |
| | | Celery | 0.14 | 0.059 | 0.0083 |
| | | Tomato | 0.09 | 0.065 | 0.0059 |
| 9 | Not Analyzed | Tomato | 0.06 | 0.065 | 0.0039 |
| 25 | 28.6 | Pepper | 0.05 | 0.066 | 0.0033 |
| | | Lettuce | 0.1 | 0.045 | 0.0045 |
| | | Beet Root | 0.11 | 0.13 | 0.014 |
| 33 | Not Analyzed | Lettuce | 0.33 | 0.045 | 0.015 |
| | | Pepper | 0.04 | 0.066 | 0.0026 |
| 34 | Not Analyzed | Radish | 0.13 | 0.055 | 0.0072 |
| | | Pepper | <0.03 | 0.066 | - |
| 41 | Not Analyzed | Tomato | 0.04 | 0.065 | 0.0026 |
| MOE Samples | | | | | |
| Sample #1 | 44.5 | Tomato | 0.1 | 0.065 | 0.0065 |
| | | Green Pepper | 0.1 | 0.066 | 0.0066 |
| Sample #2 | 58 | Pepper | 0.1 | 0.066 | 0.0066 |
| | | Tomato | 0.1 | 0.065 | 0.0065 |
| Control Samples | | | | | |
| Food Store | n/a | Beet | 0.02 | 0.13 | 0.0026 |
| | | Pepper | 0.05 | 0.066 | 0.0033 |
| | | Lettuce | 0.28 | 0.045 | 0.013 |
| Wainfleet Bog (Background Control) | 4.5 | Beet Root | 0.11 | 0.13 | 0.014 |
| | | Pepper | 0.56 | 0.066 | 0.037 |
| | | Beet Top | 0.22 | 0.091 | 0.02 |

n/a - not available.

## Table A1-9: Levels of Arsenic in Produce from Rodney Street Residences

| Location | Arsenic Soil Concentration (µg/g) | Produce Type | Dry Weight Arsenic Concentration in Produce (µg/g) | Conversion Factor (Dry Weight to Fresh Weight) | Fresh Weight Arsenic Concentration in Produce (µg/g) |
|---|---|---|---|---|---|
| JWEL 2000 Samples | | | | | |
| 3 | <0.2 | Beet Root | <0.2 | 0.13 | - |
| | | Celery | <0.2 | 0.059 | - |
| | | Tomato | <0.4 | 0.065 | - |
| 9 | Not Analyzed | Tomato | <0.4 | 0.065 | - |
| 25 | 18.6 | Pepper | <0.4 | 0.066 | - |
| | | Lettuce | <0.4 | 0.045 | - |
| | | Beet Root | <0.4 | 0.13 | - |
| 33 | Not Analyzed | Lettuce | <0.4 | 0.045 | - |
| | | Pepper | <0.2 | 0.066 | - |
| 34 | Not Analyzed | Radish | 0.2 | 0.055 | 0.011 |
| | | Pepper | <0.6 | 0.066 | - |
| 41 | Not Analyzed | Tomato | <0.4 | 0.065 | - |
| MOE Samples | | | | | |
| Sample #1 | 13 | Tomato | 0.1 | 0.065 | 0.0065 |
| | | Green Pepper | 0.1 | 0.066 | 0.0066 |
| Sample #2 | 17.5 | Pepper | 0.1 | 0.066 | 0.0066 |
| | | Tomato | 0.1 | 0.065 | 0.0065 |
| Control Samples | | | | | |
| Food Store (Control) | n/a | Beet | <0.2 | 0.13 | - |
| | | Pepper | <0.4 | 0.066 | - |
| | | Lettuce | <0.6 | 0.045 | - |
| Wainfleet Bog (Background Control) | 1.3 - 1.4 | Beet Root | <0.2 | 0.13 | - |
| | | Pepper | <0.4 | 0.066 | - |
| | | Beet Top | <0.4 | 0.091 | - |

n/a - not available.

## Table A1-10: Levels of Copper in Produce from Rodney Street Residences

| Location | Copper Soil Concentration (µg/g) | Produce Type | Dry Weight Copper Concentration in Produce (µg/g) | Conversion Factor (Dry Weight to Fresh Weight) | Fresh Weight Copper Concentration in Produce (µg/g) |
|---|---|---|---|---|---|
| JWEL 2000 Samples | | | | | |
| 3 | 134 | Beet Root | 14.8 | 0.13 | 1.92 |
| | | Celery | 5.14 | 0.059 | 0.3 |
| | | Tomato | 10.1 | 0.065 | 0.66 |
| 9 | Not Analyzed | Tomato | 11.3 | 0.065 | 0.73 |
| 25 | 194 | Pepper | 10.4 | 0.066 | 0.69 |
| | | Lettuce | 11.8 | 0.045 | 0.53 |
| | | Beet Root | 9.71 | 0.13 | 1.26 |
| 33 | Not Analyzed | Lettuce | 8.81 | 0.045 | 0.4 |
| | | Pepper | 7.09 | 0.066 | 0.47 |
| 34 | Not Analyzed | Radish | 5.2 | 0.055 | 0.29 |
| | | Pepper | 1.6 | 0.066 | 0.106 |
| 41 | Not Analyzed | Tomato | 7.93 | 0.065 | 0.52 |
| MOE Samples | | | | | |
| Sample #1 | 220 | Tomato | 4.9 | 0.065 | 0.32 |
| | | Green Pepper | 5.9 | 0.066 | 0.39 |
| Sample #2 | 325 | Pepper | 9.4 | 0.066 | 0.62 |
| | | Tomato | 4.6 | 0.065 | 0.3 |
| Control Samples | | | | | |
| Food Store (Control) | n/a | Beet | 7.78 | 0.13 | 1.01 |
| | | Pepper | 18.7 | 0.066 | 1.23 |
| | | Lettuce | 6.54 | 0.045 | 0.29 |
| Wainfleet Bog (Background Control) | 14. 9 - 22.2 | Beet Root | 7.93 | 0.13 | 1.03 |
| | | Pepper | 14.9 | 0.066 | 0.98 |
| | | Beet Top | 7.21 | 0.091 | 0.66 |

n/a - not available.

## Table A1-11: Levels of Lead in Produce from Rodney Street Residences

| Location | Lead Soil Concentration (µg/g) | Produce Type | Dry Weight Lead Concentration in Produce (µg/g) | Conversion Factor (Dry Weight to Fresh Weight) | Fresh Weight Lead Concentration in Produce (µg/g) |
|---|---|---|---|---|---|
| JWEL 2000 Samples | | | | | |
| 3 | 379 | Beet Root | 6.26 | 0.13 | 0.81 |
| | | Celery | 4.16 | 0.059 | 0.25 |
| | | Tomato | 0.1 | 0.065 | 0.0065 |
| 9 | Not Analyzed | Tomato | 0.12 | 0.065 | 0.0078 |
| 25 | 371 | Pepper | 0.15 | 0.066 | 0.0099 |
| | | Lettuce | 0.93 | 0.045 | 0.042 |
| | | Beet Root | 8.11 | 0.13 | 1.05 |
| 33 | Not Analyzed | Lettuce | 2.43 | 0.045 | 0.11 |
| | | Pepper | 2.55 | 0.066 | 0.17 |
| 34 | Not Analyzed | Radish | 2.55 | 0.055 | 0.14 |
| | | Pepper | 0.58 | 0.066 | 0.038 |
| 41 | Not Analyzed | Tomato | <0.1 | 0.065 | - |
| MOE Samples | | | | | |
| Sample #1 | 91.5 | Tomato | 0.25 | 0.065 | 0.016 |
| | | Green Pepper | 0.25 | 0.066 | 0.017 |
| Sample #2 | 88 | Pepper | 0.6 | 0.066 | 0.04 |
| | | Tomato | 1.9 | 0.065 | 0.12 |
| Control Samples | | | | | |
| Food Store Control | n/a | Beet | 0.17 | 0.13 | 0.022 |
| | | Pepper | 0.13 | 0.066 | 0.0086 |
| | | Lettuce | 0.23 | 0.045 | 0.01 |
| Wainfleet Bog (Background Control) | 10.9 - 11 | Beet Root | 0.1 | 0.13 | 0.013 |
| | | Pepper | 0.15 | 0.066 | 0.0099 |
| | | Beet Top | 0.35 | 0.091 | 0.032 |

n/a - not available.

## Table A1-12a: Levels of Nickel in Produce from Rodney Street Residences (JWEL & MOE 2000 Samples)

| Location | Nickel Soil Concentration (µg/g) | Produce Type | Dry Weight Nickel Concentration in Produce (µg/g) | Conversion Factor (Dry Weight to Fresh Weight) | Fresh Weight Nickel Concentration in Produce (µg/g) |
|---|---|---|---|---|---|
| JWEL 2000 Samples | | | | | |
| 3 | 764 | Beet | 14 | 0.13 | 1.82 |
| | | Celery | 4.2 | 0.059 | 0.248 |
| | | Tomato | 3.2 | 0.065 | 0.208 |
| 6 | 99.5 | Onion | 0.3 | 0.11 | 0.033 |
| | | Pear | 0.6 | 0.17 | 0.102 |
| | | Pepper | 2.7 | 0.066 | 0.178 |
| 8 | 188 | Apple | 0.05* | 0.15 | 0.0075 |
| | | Lettuce | 5.7 | 0.045 | 0.256 |
| | | Pepper | 6 | 0.066 | 0.396 |
| 17 | 157 | Beet | 1 | 0.13 | 0.13 |
| | | Pepper | 1.3 | 0.066 | 0.0858 |
| 19 | 380 | Apple | 0.2 | 0.15 | 0.03 |
| | | Beet | 1.1 | 0.13 | 0.143 |
| | | Cantaloupe | 3.3 | 0.1 | 0.33 |
| | | Peach | 2.8 | 0.11 | 0.308 |
| | | Pear | 3.2 | 0.17 | 0.544 |
| | | Pepper | 4.1 | 0.066 | 0.271 |
| | | Plum | 1.6 | 0.21 | 0.336 |
| | | Tomato | 2.5 | 0.065 | 0.162 |
| | | Watermelon | 7.1 | 0.1 | 0.71 |
| 20 | 333 | Beet | 1.9 | 0.13 | 0.247 |
| | | Pepper | 6.1 | 0.066 | 0.403 |
| 23 | 472 | Grapes | 0.2 | 0.19 | 0.038 |
| | | Pepper | 8.3 | 0.066 | 0.548 |
| 24 | 296 | Apple | 0.2 | 0.15 | 0.03 |
| | | Lettuce | 4.2 | 0.045 | 0.189 |
| | | Pepper | 4.9 | 0.066 | 0.323 |
| 25 | 1570 | Pepper | 7.9 | 0.066 | 0.521 |
| | | Lettuce | 7 | 0.045 | 0.315 |
| | | Beet | 10.5 | 0.13 | 1.36 |
| 26 | 516 | Rhubarb | 1.2 | 0.052 | 0.0624 |
| | | Squash | 1.5 | 0.057 | 0.0855 |
| | | Tomato | 1.2 | 0.065 | 0.078 |
| 37 | 293 | Celery | 1.5 | 0.059 | 0.0885 |

| Location | Nickel Soil Concentration (µg/g) | Produce Type | Dry Weight Nickel Concentration in Produce (µg/g) | Conversion Factor (Dry Weight to Fresh Weight) | Fresh Weight Nickel Concentration in Produce (µg/g) |
|---|---|---|---|---|---|
| | | Pepper | 10.4 | 0.066 | 0.686 |
| 42 | 302 | Leeks | 1.9 | 0.124 | 0.236 |
| | | Pepper | 12.2 | 0.066 | 0.805 |
| 43 | 135 | Carrot | 0.7 | 0.12 | 0.084 |
| | | Pepper | 2.9 | 0.066 | 0.191 |
| MOE Samples | | | | | |
| MOE Sample | 2750 | Pepper | 14 | 0.066 | 0.924 |
| | | Tomato | 5.3 | 0.065 | 0.344 |
| Control Samples | | | | | |
| Food Store Control | n/a | Beet | 0.1 | 0.13 | 0.013 |
| | | Pepper | 0.2 | 0.066 | 0.013 |
| | | Lettuce | 0.6 | 0.045 | 0.027 |
| Wainfleet Bog (Background Control) | 15.4 - 15.8 | Beet Root | 0.3 | 0.13 | 0.039 |
| | | Pepper | 4.8 | 0.066 | 0.317 |
| | | Beet Top | 0.6 | 0.091 | 0.055 |

* This value is one half the detection limit.

### Table A1-12b: Levels of Nickel in Produce from Rodney Street Residences (Data Provided by JWEL at Time of Report Finalization)

| Date Collected | JWEL Sample # | Produce Sampled | Dry Weight Nickel Concentration (µg/g) | Dry to Wet Conversion Factor | Wet Weight Concentration (µg/g) |
|---|---|---|---|---|---|
| Sept. 5 | FBS5S32B | apple | 0.2 | 0.161 | 0.032 |
| Sept. 7 | FBS7S62B | apple | 0.4 | 0.161 | 0.064 |
| Sept. 5 | FBS5S25B | apples | 0.5 | 0.161 | 0.081 |
| Sept. 6 | FBS6S48A | apples | 6.7 | 0.161 | 1.079 |
| Sept. 7 | FBS7S63A | apples | 0.3 | 0.161 | 0.048 |
| Sept. 7 | FBS7S64E | apples | 0.5 | 0.161 | 0.081 |
| Sept. 7 | FBS7S62G | basil | 32.7 | 0.045 | 1.472 |
| Sept. 5 | FBS5S15A | beans | 11.3 | 0.057 | 0.640 |
| Sept. 7 | FBS7S53D | beans | 9 | 0.057 | 0.510 |
| Sept. 7 | FBS7S61B | beans | 5.8 | 0.057 | 0.328 |
| Sept. 5 | FBS5S16A | beets | 4.2 | 0.094 | 0.395 |
| Sept. 5 | FBS5S26A | beets | 2.1 | 0.161 | 0.338 |
| Sept. 5 | FBS5S28B | beets | 0.7 | 0.108 | 0.076 |
| Sept. 6 | FBS6S42B | beets | 14.6 | 0.121 | 1.767 |
| Sept. 7 | FBS6S51A | beets | 2.1 | 0.121 | 0.254 |
| Sept. 7 | FBS7S61C | beets | 38.4 | 0.121 | 4.646 |
| Sept. 7 | FBS7S64D | beets | 9.4 | 0.121 | 1.137 |
| Sept. 11 | FBS11S68A | beets | 5.9 | 0.121 | 0.714 |

| Date Collected | JWEL Sample # | Produce Sampled | Dry Weight Nickel Concentration (µg/g) | Dry to Wet Conversion Factor | Wet Weight Concentration (µg/g) |
|---|---|---|---|---|---|
| Sept. 11 | FBS11S70A | beets | 1.8 | 0.121 | 0.218 |
| Sept. 11 | FBS12S72A | beets | 3.1 | 0.121 | 0.375 |
| Sept. 7 | FBS7S62I | broccoli | 30.9 | 0.100 | 3.090 |
| Sept. 6 | FBS6S36B | cabbage | 9.6 | 0.045 | 0.432 |
| Sept. 5 | FBS5S22C | carrots | 3.2 | 0.089 | 0.285 |
| Sept. 5 | FBS5S28A | carrots | 0.6 | 0.091 | 0.055 |
| Sept. 5 | FBS5S30C | carrots | 0.7 | 0.368 | 0.258 |
| Sept. 6 | FBS6S34A | carrots | 1.2 | 0.183 | 0.219 |
| Sept. 6 | FBS6S40A | carrots | 0.4 | 0.183 | 0.073 |
| Sept. 6 | FBS6S42A | carrots | 9.2 | 0.183 | 1.681 |
| Sept. 6 | FBS6S49D | carrots | 2.6 | 0.183 | 0.475 |
| Sept. 7 | FBS6S51B | carrots | 3.4 | 0.183 | 0.621 |
| Sept. 7 | FBS7S59B | carrots | 19.6 | 0.183 | 3.580 |
| Sept. 7 | FBS7S63C | carrots | 3.6 | 0.183 | 0.658 |
| Sept. 7 | FBS7S64B | carrots | 9.4 | 0.183 | 1.717 |
| Sept. 11 | FBS11S69A | carrots | 6.6 | 0.183 | 1.206 |
| Sept. 11 | FBS11S70B | carrots | 2.9 | 0.183 | 0.530 |
| Sept. 11 | FBS11S71A | carrots | 3.3 | 0.183 | 0.603 |
| Sept. 12 | FBS12S74A | carrots | 22.2 | 0.183 | 4.055 |
| Sept. 5 | FBS5S21B | celery | 0.8 | 0.101 | 0.081 |
| Sept. 5 | FBS5S33A | celery | 19.4 | 0.101 | 1.959 |
| Sept. 6 | FBS6S36C | celery | 0.5 | 0.101 | 0.051 |
| Sept. 6 | FBS6S49B | celery | 30.9 | 0.101 | 3.121 |
| Sept. 5 | FBS5S17B | cucumber | 4.3 | 0.036 | 0.155 |
| Sept. 5 | FBS5S26C | cucumber | 2.7 | 0.050 | 0.135 |
| Sept. 7 | FBS7S52C | cucumber | 2.7 | 0.050 | 0.135 |
| Sept. 7 | FBS7S53B | cucumber | 7.6 | 0.050 | 0.380 |
| Sept. 7 | FBS7S55C | cucumber | 14.7 | 0.050 | 0.735 |
| Sept. 7 | FBS7SS60B | cucumber | 4 | 0.050 | 0.200 |
| Sept. 5 | FBS5S19B | eggplant | 3.1 | 0.093 | 0.288 |
| Sept. 6 | FBS6S49C | eggplant | 1.3 | 0.093 | 0.121 |
| Sept. 7 | FBS7S62F | fennel | 7.8 | 0.0121 | 0.944 |
| Sept. 7 | FBS7S62A | grapes | 0.8 | 0.190 | 0.152 |
| Sept. 12 | FBS12S73A | horseradish | 9.2 | 0.050 | 0.460 |
| Sept. 11 | FBS11S66C | jerusaleum potato | 13.5 | 0.133 | 1.796 |
| Sept. 5 | FBS5S22A | leek | 3.5 | 0.079 | 0.277 |
| Sept. 5 | FBS5S29B | leek | 2.4 | 0.127 | 0.305 |
| Sept. 7 | FBS7S62H | leek | 6.4 | 0.103 | 0.659 |
| Sept. 7 | FBS7S64C | leek | 11.6 | 0.103 | 1.195 |
| Sept. 5 | FBS5S23B | leeks | 1.9 | 0.103 | 0.196 |
| Sept. 5 | FBS5S19A | lettuce | 8.1 | 0.060 | 0.486 |
| Sept. 5 | FBS5S26B | lettuce | 2.8 | 0.068 | 0.190 |
| Sept. 5 | FBS5S33C | lettuce | 15.9 | 0.064 | 1.018 |
| Sept. 6 | FBS6S36A | lettuce | 8 | 0.064 | 0.512 |
| Sept. 6 | FBS6S49A | lettuce | 1.9 | 0.064 | 0.122 |
| Sept. 11 | FBS11S65B | muskmelon | 2 | 0.100 | 0.200 |

| Date Collected | JWEL Sample # | Produce Sampled | Dry Weight Nickel Concentration (µg/g) | Dry to Wet Conversion Factor | Wet Weight Concentration (µg/g) |
|---|---|---|---|---|---|
| Sept. 5 | FBS5S20C | onion | 0.6 | 0.046 | 0.028 |
| Sept. 5 | FBS5S21A | onion | 4.5 | 0.175 | 0.788 |
| Sept. 5 | FBS5S30B | onion | 4.8 | 0.052 | 0.250 |
| Sept. 6 | FBS6S47A | onion | 1.6 | 0.091 | 0.146 |
| Sept. 7 | FBS7S55D | onion | 2.6 | 0.091 | 0.237 |
| Sept. 7 | FBS7SS60C | onion | 4.6 | 0.091 | 0.419 |
| Sept. 7 | FBS7S61D | onion | 15.6 | 0.091 | 1.420 |
| Sept. 7 | FBS7S62E | onion | 9.5 | 0.091 | 0.865 |
| Sept. 11 | FBS11S67A | onion | 1.4 | 0.091 | 0.127 |
| Sept. 6 | FBS6S43B | parsnip | 7.2 | 0.200 | 1.44 |
| Sept. 7 | FBS7S64A | parsnip | 14.1 | 0.200 | 2.82 |
| Sept. 5 | FBS5S19C | peach | 4.8 | 0.114 | 0.547 |
| Sept. 5 | FBS5S32A | peach | 1 | 0.114 | 0.114 |
| Sept. 5 | FBS5S33D | peach | 2.7 | 0.114 | 0.308 |
| Sept. 7 | FBS7S62C | peach | 9.7 | 0.114 | 1.106 |
| Sept. 5 | FBS5S19D | pear | 2.6 | 0.057 | 0.148 |
| Sept. 5 | FBS5S31A | pear | 0.7 | 0.230 | 0.161 |
| Sept. 6 | FBS5S31B | pear(dup) | 1 | 0.240 | 0.240 |
| Sept. 5 | FBS5S25A | pears | 1.7 | 0.154 | 0.262 |
| Sept. 5 | FBS5S23C | pear | 1.1 | 0.170 | 0.187 |
| Sept. 6 | FBS6S35A | pear | 0.8 | 0.170 | 0.136 |
| Sept. 6 | FBS6S36E | pear | 5.4 | 0.170 | 0.919 |
| Sept. 6 | FBS6S45B | pear | 0.3 | 0.170 | 0.051 |
| Sept. 7 | FBS7S62D | pear | 2.1 | 0.170 | 0.358 |
| Sept. 7 | FBS7S64F | pear | 1.6 | 0.170 | 0.272 |
| Sept. 6 | FBS6S48B | pears | 0.3 | 0.170 | 0.051 |
| Sept. 6 | FBS6S49E | pears | 1.9 | 0.170 | 0.323 |
| Sept. 6 | FBS7S63B | pears | 4.7 | 0.170 | 0.800 |
| Sept. 5 | FBS5S17C | peppers | 11.1 | 0.167 | 1.854 |
| Sept. 5 | FBS5S22D | peppers | 15.3 | 0.082 | 1.255 |
| Sept. 5 | FBS5S33B | peppers | 8.6 | 0.125 | 1.071 |
| Sept. 6 | FBS6S34B | peppers | 3.5 | 0.125 | 0.436 |
| Sept. 6 | FBS6S42D | peppers | 16.5 | 0.125 | 2.054 |
| Sept. 6 | FBS6S44B | peppers | 5.5 | 0.125 | 0.685 |
| Sept. 6 | FBS6S50A | peppers | 41.5 | 0.125 | 5.167 |
| Sept. 7 | FBS7S52A | peppers | 19.9 | 0.125 | 2.478 |
| Sept. 7 | FBS7S55B | peppers | 26.9 | 0.125 | 3.349 |
| Sept. 7 | FBS7S59C | peppers | 40.2 | 0.125 | 5.005 |
| Sept. 11 | FBS11S67B | peppers | 11.9 | 0.125 | 1.482 |
| Sept. 5 | FBS5S28E | plum | 0.3 | 0.185 | 0.056 |
| Sept. 7 | FBS6S40B | plum | 0.3 | 0.185 | 0.056 |
| Sept. 6 | FBS6S43C | plum | 0.4 | 0.185 | 0.074 |
| Sept. 5 | FBS5S21C | potato | 2.9 | 0.068 | 0.197 |
| Sept. 5 | FBS5S28D | potato | 0.5 | 0.129 | 0.065 |
| Sept. 5 | FBS5S29A | potato | 1 | 0.202 | 0.202 |
| Sept. 5 | FBS5S23A | potato | 0.5 | 0.133 | 0.067 |

| Date Collected | JWEL Sample # | Produce Sampled | Dry Weight Nickel Concentration (µg/g) | Dry to Wet Conversion Factor | Wet Weight Concentration (µg/g) |
|---|---|---|---|---|---|
| Sept. 6 | FBS6S43A | potato | 0.7 | 0.133 | 0.093 |
| Sept. 11 | FBS11S66B | potato | 1.8 | 0.133 | 0.239 |
| Sept. 7 | FBS7S62J | radichio | 14.1 | 0.045 | 0.635 |
| Sept. 7 | FBS7S59A | radish | 10.8 | 0.050 | 0.540 |
| Sept. 7 | FBS7S51C | rhubarb | 2.4 | 0.052 | 0.125 |
| Sept. 7 | FBS7S53C | rhubarb | 2.1 | 0.052 | 0.109 |
| Sept. 5 | FBS5S17A | squash | 13.6 | 0.065 | 0.884 |
| Sept. 5 | FBS5S30A | squash | 2.3 | 0.093 | 0.214 |
| Sept. 11 | FBS11S65A | squash | 1.4 | 0.079 | 0.111 |
| Sept. 11 | FBS11S66A | squash | 5.2 | 0.079 | 0.411 |
| Sept. 5 | FBS5S15C | swiss chard | 35.9 | 0.062 | 2.226 |
| Sept. 5 | FBS5S28C | swiss chard | 0.8 | 0.055 | 0.044 |
| Sept. 5 | FBS5S15B | tomato | 6.1 | 0.073 | 0.445 |
| Sept. 5 | FBS5S16B | tomato | 0.9 | 0.051 | 0.046 |
| Sept. 5 | FBS5S18A | tomato | 6 | 0.044 | 0.266 |
| Sept. 5 | FBS5S20B | tomato | 0.5 | 0.048 | 0.024 |
| Sept. 5 | FBS5S22B | tomato | 2.6 | 0.052 | 0.135 |
| Sept. 5 | FBS5S24A | tomato | 0.8 | 0.047 | 0.038 |
| Sept. 5 | FBS5S27A | tomato | 0.5 | 0.052 | 0.026 |
| Sept. 6 | FBS6S38A | tomato | 0.6 | 0.052 | 0.031 |
| Sept. 6 | FBS6S39A | tomato | 1.3 | 0.052 | 0.068 |
| Sept. 6 | FBS6S42C | tomato | 5.1 | 0.052 | 0.268 |
| Sept. 6 | FBS6S44A | tomato | 6.9 | 0.052 | 0.362 |
| Sept. 6 | FBS6S45A | tomato | 1 | 0.052 | 0.052 |
| Sept. 6 | FBS6S46A | tomato | 23.1 | 0.052 | 1.212 |
| Sept. 7 | FBS7S52B | tomato | 0.9 | 0.052 | 0.047 |
| Sept. 7 | FBS7S53A | tomato | 1.4 | 0.052 | 0.073 |
| Sept. 7 | FBS7S55A | tomato | 2.9 | 0.052 | 0.152 |
| Sept. 7 | FBS7S59D | tomato | 28 | 0.052 | 1.469 |
| Sept. 7 | FBS7SS60A | tomato | 31.1 | 0.052 | 1.632 |
| Sept. 7 | FBS7S61S | tomato | 8.3 | 0.052 | 0.435 |
| Sept. 5 | FBS5S20A | watermelon | 1.1 | 0.059 | 0.065 |
| Sept. 5 | FBS5S24B | zucchini | 1.6 | 0.038 | 0.061 |

### Table A1-12c: Summary of Nickel in Produce from Rodney Street Residences (2000 and 2001 Samples Combined)

| Summary Statistic | Wet Weight Nickel Concentration (µg/g) |
|---|---|
| average | 0.63 |
| 95th%ile | 2.44 |
| maximum | 5.17 |
| median | 0.28 |

# Appendix 2

# Toxicity Assessment

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## Toxicity Assessment

### A2-1 Introduction

The chemical screening section of the main report identified eight metals as being potential human health concerns in the Rodney Street area of Port Colborne. A toxicity assessment was compiled for these metals. The objectives of the toxicity assessment are:

- to provide the reader with a brief understanding of the toxicological effects that have been reported to be associated with exposure to the chemicals of concern;
- to identify whether each metal of concern is considered to have carcinogenic or non-carcinogenic effects and;
- to identify suitable exposure limits against which exposures can be compared to provide estimates of potential health risks.

The toxicological profiles are **not** intended to:

- be exhaustive examinations of all the toxicological information available for each metal;
- be used to develop exposure limits for exposure routes where no exposure limits are available, or;
- critically review and/or modify currently existing exposure limits set by Agencies such as the US EPA, WHO, Health Canada, etc.

This toxicity assessment outlines the toxicological effects that have been reported to be associated with inhalation, ingestion and dermal contact exposures to antimony, arsenic, beryllium, cadmium, cobalt, copper, lead and nickel, and identifies whether each metal should be considered as a carcinogen or a non-carcinogen based on the exposure pathway. The type of exposure limit selected is dependent upon whether a compound is considered to have non-carcinogenic or carcinogenic effects, however, in some cases, eg., lead and cobalt, cancer potency factors are not available. The types of exposure limits associated with both types of compounds are discussed below.

The relevance of toxicological endpoints derived from animal studies to humans is a challenging task from a risk assessment perspective. The primary difficulty is that the contaminant levels the study animals are typically exposed to are much higher than exposures faced by human populations. The effects of these high exposures are assessed by a variety of histopathological methods.

In most cases, the molecular mechanisms causing the metal related adverse effects are not well understood, and in many cases, there is the uncertainty that the mechanisms leading to an adverse effect may differ between species as well as between the route of exposure. In addition, many animal studies are based on a metal species that is convenient to administer but may not be the one to which human populations are exposed.

The finding of adverse effects in animals is then related to human populations by the use of uncertainty factors. Uncertainty factors provide a safety margin in the extrapolation of the estimates of adverse effects when the mechanisms leading to adverse effects are not well understood (discussed later in this section).

There are cases where animal studies and occupational health studies of the adverse effects of nickel have shown certain similarities. For example, as discussed in section A2-9.2.1, an occupational exposure study carried out by Chashschin et al., 1994 clearly indicated various health impairments such as respiratory, skin, cardiovascular diseases and adverse reproductive outcomes in Russian nickel refinery workers directly exposed to at least 130 ug/m$^3$, and as high as 200 ug/m$^3$ nickel.

These findings parallel respiratory and reproductive effects shown in animal studies (see sections A2-9.2.1, A2-9.2.3). While the adverse effects of nickel are apparent in controlled animal studies, it is difficult to draw conclusive parallels with the occupational health study as the routes of exposure differ.

Similarly, nickel refinery workers exposed to elevated levels of nickel refinery dust exhibited changes in lung opacity (non-cancer endpoint) as well as nasal and lung cancer (see sections A2-9.2.1). Test animals exposed to nickel refinery dust aerosols and aerosols of individual insoluble nickel species (nickel oxide, nickel sulphide) developed increased incidences of lung tumors in some cases (see section A2-9.2.3.2).

However, in many cases, regulators are faced with evaluation of studies that are not exactly applicable but are the best available. This makes it a difficult task to correlate the findings from animal studies to humans. This is a point of uncertainty in relating the findings of a controlled animal study to an uncontrolled human health survey.

The toxicological profiles also examine the effect that the route of exposure has on the toxicological activity of each compound. For some compounds, the route by which the compound enters the body can have a marked effect on the toxicological effects that occur. In cases where the toxicological effects of a chemical differ between the routes of exposure, it is necessary to assess inhalation and ingestion exposures independently. For example, exposure to beryllium, cadmium and nickel by inhalation may be carcinogenic, but the data suggests they are unlikely to be carcinogenic if the exposure is via ingestion. However, arsenic may be carcinogenic following either inhalation or ingestion exposure. Therefore, where route-specific exposure limits are available, the toxicological profiles will provide both. In cases where exposure limits are available for a single route of exposure, the toxicological profiles will not develop exposure limits by route-to-route extrapolation. Although complex route-to-route extrapolation is undertaken in some situations, it is typically discouraged by the US EPA and similar regulatory agencies because it requires detailed knowledge of pharmacokinetic and pharmacodynamic factors and extensive modelling. All of which are beyond the scope of the current assessment.

The health risk of antimony (Sb)(MOE, 1991), arsenic (As)(MOE, 1991, 1999, 2001), cadmium (Cd)(MOE, 1991, 1999), cobalt (Co)(MOE, 1991, 1998, 1999), copper (Cu)(MOE, 1991, 1998, 1999), lead (Pb)(MOE, 1991; MOEE, 1994; MOE, 1999) and nickel (Ni)(MOE, 1991; MOE, 1998; MOE, 1999) exposure in Ontario soils has been assessed in detail for several Ontario communities. These appendices offer supplementary information to chapter 3 of the main report (Part B). The references used in the development of each toxicological profile are provided at the end of each profile.

The selection of exposure limits (cancer and non-cancer) requires consideration of a number of important attributes of the available values. The framework and methodologies for developing exposure limits are well described by all major agencies.

Evaluation of any study used to estimate human health risk based on either toxicity testing in laboratory animals or an epidemiological study of exposed humans, utilizes extensive scientific criteria to determine the reliability of the testing protocols used. Other factors, such as the health of the animals during the test, the appropriate determination of toxicity endpoints, the statistical significance of any dose-response relationships found, and the occurrence of any confounding factors that affect the results are also considered. Epidemiological studies have a different set of rules to determine causal association between disease endpoints and human exposure patterns.

In terms of animal testing studies, the age of the study is not necessarily as important as the following of recognized and approved protocols for treating and exposing the animals to the substance being tested and identifying the resulting adverse effects. The statistical reliability of the data demonstrating the presence or absence of adverse health endpoints or any apparent dose-response relationship arising from the study are an important factor. More recent testing information generally benefits from more recent developments in toxicology and adds to the weight of evidence used to develop exposure limits.

Adoption of a particular animal testing (or epidemiology) study by regulatory agencies as supporting documentation for their exposure limits, is an important criterion for evaluation and selection of relevant toxicological information. Regulatory agencies then use such criteria to select studies to support the development of exposure limits (R*f*D, TDI, etc.). In addition, using the dose-response (or comparable extrapolation techniques from epidemiology studies), agencies apply UFs for threshold, non-cancer endpoints, or mathematical low dose extrapolation methods for non-threshold, cancer endpoints.

For practical purposes, chemicals that exhibit threshold-type dose-response relationships, it is assumed that there exists a threshold of exposure below which the possibility of adverse effects is extremely low, in other words, at rates of exposure where no measurable impacts would occur. This threshold or limit is commonly referred to as a reference dose (R*f*D), or allowable daily intake (ADI). Conservative estimates of this threshold are based on the application of "safety factors" or "uncertainty factors" (US FDA, 1982; US EPA, 1989; Health Canada, 1993) to a NOAEL that has been determined experimentally, usually in animals, occasionally through controlled studies in people. The magnitude of these "safety factors" or "uncertainty factors", depends on the level of confidence in the use of available data as a basis for extrapolation to the exposure scenario of the risk assessment. This confidence is dependent on differences in species and duration of exposure, information on the variability in sensitivity among individuals, and the quality of available data (ie., the weight of evidence of the supporting data).

Uncertainty factors are derived for a specific chemical on a case-by-case basis, depending principally on the quality of the available toxicological database. Generally, a factor of one to ten is used to account for intraspecies variation and interspecies variation. An additional factor of 1 to 100 is used to account for inadequacies of the database which include but are not necessarily limited to, lack of adequate data on developmental, chronic or reproductive toxicity, use of a LO(A)EL versus a NO(A)EL and inadequacies of the critical study. An additional uncertainty factor ranging between one and five may be incorporated where there is sufficient information to indicate a potential for interaction with other chemical substances commonly present in the general environment. If the chemical substance is essential or beneficial for human health, the dietary requirement is also taken into consideration in derivation of the Tolerable Daily Intake or Concentration. Exceptionally, in deriving an exposure limit for severe effects (eg., teratogenicity), an additional uncertainty factor of one to ten may be incorporated. Numerical values of the uncertainty factor normally range from 1 to 10,000. Uncertainty factors greater than 10,000 are not applied since the limitations of such a database are sufficient to preclude development of a reliable exposure limit.

Expert judgement is required in both the application of uncertainty factors to the identified threshold value and the extrapolation to low dose estimates. While RfD or risk-based concentrations can be generated using all the appropriate risk assessment protocols and principles, the resulting exposure limits may not be immediately achievable. This may be due to background concentrations, intakes from specific pathways, technical feasibility or other reasons, though none of these reasons should necessarily preclude the use of well documented and reviewed exposure limits. It should be noted that just because one exposure limit is lower than another does not necessarily imply that the limit provides additional safety, since most exposure limits incorporate adequate margins of safety. Also, how an exposure limit is applied to reduce risk can have implications for the ultimate "safety" of the value. Consequently, while exposure limits from different agencies using current, reliable toxicological information may vary, any claims as to their relative safety vis-a-vis each other requires an assessment of how the exposure limits are applied.

In this document, the term *μg/kg body weight-day* will be abbreviated as μg/kg-day.

### A2-1.1 Exposure Limits for Non-Carcinogenic Compounds

Non-carcinogenic compounds are generally considered to act on the body through threshold mechanisms. This means that at low doses the body is able to detoxify and remove the compounds from the body without the compounds causing adverse or toxic effects. As the dose or exposure to a compound increases, the body's ability to detoxify and clear the compound is reduced. When exposure exceeds the body's ability to detoxify and excrete the compound, it can cause adverse or toxic effects. The point at which this occurs is called the threshold. The threshold is different for every compound. The exposure limits developed for each compound reflect the threshold for each chemical.

Contaminants of concern were assessed for both cancer potential and adverse health effects other than cancer. Toxic effects other than cancer may play an important role in the overall toxicity of the metals. Table A2-1 provides a brief summary of the major toxic effects, other than cancer, of the selected metals.

## Table A2-1: Major Toxic Effects (Other Than Cancer) in Humans Following Elevated Exposures to Metals of Concern

| Substance | Health Effects | Reference |
|---|---|---|
| Antimony | Nausea, vomiting, diarrhea, cardiovascular effects and GI disorders | US EPA IRIS, 1998a; WHO,1996a |
| Arsenic | Abdominal pain, vomiting, diarrhea, muscular pain, flushing of skin, dermal lesions, neuropathy, and peripheral vascular disease | US EPA IRIS, 1998b;<br>WHO,1998a;<br>ATSDR, 1993a |
| Beryllium | Lung disease, no reported oral toxicity | US EPA IRIS, 1998c; ATSDR, 1993b |
| Cadmium | Kidney damage, also respiratory effects that tend to be reversible with discontinuation of exposure | US EPA IRIS, 1998d;<br>WHO,1996b;<br>ATSDR, 1999 |
| Cobalt | Essential element (part of vitamin $B_{12}$), cardiovascular effects, lung disease, allergic contact dermatitis, rhinitis and asthma | ATSDR, 1992 |
| Copper | Essential nutrient, lung disease, kidney disease, skin irritation and eczema, abdominal pain, nausea, vomiting, diarrhea, liver damage | US EPA IRIS 1998e; WHO, 1998b; ATSDR, 1990 |
| Lead | Tiredness, sleeplessness, irritability, headaches, joint pain, GI symptoms, peripheral neuropathy, kidney disease, hypertension, anemia, damage to central and peripheral nervous system, effects in behaviour and intellectual development | US EPA IRIS 1998f;<br>WHO,1996c;<br>ATSDR, 1993c;<br>MOEE, 1993 |
| Nickel | Allergic lung disease, reproductive effects, kidney disease and allergic contact dermatitis | US EPA IRIS 1998g,h,i;<br>WHO,1993, 1996d, 1998c; ATSDR, 1997 |

Non-cancer exposure limits by inhalation and oral routes are summarized in tables A2-2 and A2-3.

## Table A2-2: Non-Cancer Inhalation Exposure Limits of Metals of Concern, Expressed as Air Concentrations (µg/m$^3$)

| Substance | Sources | | |
|---|---|---|---|
| | US EPA[1] | WHO[2] | CEPA/CCME[3] |
| Antimony | 0.2 | NA | NA |
| Arsenic | NA | NA | NA |
| Beryllium | 0.02 | NA | NA |
| Cadmium | NA | 0.005 | NA |
| Cobalt | NA (0.03-ATSDR) | NA | NA |
| Copper | NA (2.4 California) | NA | NA |
| Lead | NA | 0.5 | NA |
| Nickel | | | |
| Metallic | NA | NA | 0.018 |
| Soluble Salts | NA (0.2 ATSDR[4]) | NA | 0.0035 |
| Nickel Refinery Dust | NA | NA | 0.02 (nickel oxide) |

1. US EPA IRIS database; 2. WHO, Air Quality Guidelines for Europe, 2000; 3. Health Canada, 1996a; 4. ATSDR, 1997

## Table A2-3: Non-Cancer Oral Exposure Limits of Metals of Concern, Expressed as Intakes (µg/kg/day)

| Substance | Sources | | |
|---|---|---|---|
| | US EPA[1] | WHO[2] | CEPA/CCME[3] |
| Antimony | 0.4 | 0.86 | NA |
| Arsenic | 0.3 | 2 | NA |
| Beryllium | 2 | NA | NA |
| Cadmium | 1 | 1 | NA |
| Cobalt | 60 [4] | NA | NA |
| Copper | NA (140 [5]) | 2000 | (100) |
| Lead | NA | 3.5 | 3.57 |
| Nickel | | | |
| Soluble Salts | 20 | (5)[6] | 1.3 (nickel chloride)<br>50 (nickel sulphate) |
| Nickel Refinery Dust | NA | NA | NA |

1. US EPA IRIS database , 2. WHO Drinking Water Guideline documentation, 1996-1998, 3. Health Canada, 1996a,b and CCME , 1997; 4. US EPA Region III, 2001; 5. IOM, 2001; 6. see section A2-9.3.2

The US EPA is a reliable source of exposure limits or reference doses (RfD) for ingestion exposures and reference concentration (RfC) for inhalation exposures, that are developed from toxicological studies of human or animal populations. These are set to ensure that chronic exposures to a chemical at concentrations that are at or below the exposure limit will not result in adverse effects. The US EPA defines the RfD/RfC as;

> *A quantitative estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of non-carcinogenic, deleterious effects during a life-time.*

The US EPA RfD/RfC values are based on life-time averaged exposures. This means that limited exposures to a compound that exceed an exposure limit will not result in adverse effects, provided that over a life-time, the averaged daily dose does not exceed the exposure limit. The exposure limit is set to prevent the accumulation of the compound in the body at levels that exceed the threshold and therefore limit the possibility of adverse health effects occurring.

The RfD/RfC values are intended to be used as life-time average daily exposures and therefore, in assessing potential risks for an exposed individual or population, life-time averaged daily doses should be used if the exposures are expected to occur over a life-time. The US EPA Risk Assessment Guidance for Superfund (RAGS*)* recommends that in the assessment of risks associated with exposures to non-carcinogenic compounds that life-time averaged exposures be used to assess risks when exposures occur over a life-time (US EPA, 1989). The RAGS further notes that the comparison of short-term or non-life-time exposures to RfD/RfC values should only be used as a screening exercise to determine if a potential human health risk would be predicted based on estimated exposures. Short-term exposures that are below the chronic exposure limit are not a concern for adverse human health effects (US EPA, 1989). Life-time chronic daily intakes (CDI) are calculated as shown in equation A2-1.

**Eq A2-1**

$$\textit{Total CDI} = \sum_{1}^{n} \frac{(Intake_{(1..n)} \times Time_{(1..n)})}{(B.W._{(1..n)} \times 70 years)}$$

| | | | | |
|---|---|---|---|---|
| Where: | Total CDI | = | Total Chronic Daily Dose | µg/kg-day |
| | $Intake_{1..n}$ | = | Estimated Daily Intake (EDI) of age group n | µg/kg-day |
| | $Time_{1..n}$ | = | Time spent in each age group | years |
| | BW | = | Bodyweight of receptor | kg |

It is important to note that the total CDI value can also be referred to as a life-time averaged daily dose (LADD).

### A2-1.2 Exposure Limits for Carcinogenic Compounds

The assessment of the carcinogenic potential of chemicals is undertaken by several major agencies and MOE relied on their classifications to characterize the potential for health effects and to select appropriate exposure limits.

## Cancer Classification

The International Agency for Research in Cancer (IARC), was the first organization to develop a weight of evidence scheme whereby a panel of international experts systematically evaluates the evidence for and against carcinogenicity of a given agent. The IARC panel then publishes the carcinogenic ranking for a given agent, which summarizes the weight of evidence for its potential to induce cancer in humans. IARC is a part of the World Health Organization (WHO).

Although the IARC ranking continues to be highly respected, other agencies have developed similar ranking schemes. Of these, the one published by the US EPA (1986) is probably the most influential. In 1996, US EPA replaced its ranking scheme based on letter ranks with a new descriptive scheme, which takes into account a wider range of data. The US EPA's 1986 scheme is still widely used, in part because the evaluations based on this earlier ranking scheme continues to be reported in the Integrated Risk Information System (IRIS) database. The ranking schemes by IARC and US EPA (1986) are quite similar. Although both organizations place a greater emphasis on reliable human epidemiological studies than on animal data, US EPA has traditionally placed heavier emphasis on animal data than IARC. The new US EPA (1996) ranking scheme has only been in use for a few years, so the number of agents ranked by this scheme is still relatively small.

In Canada, Health Canada has developed a carcinogen-ranking scheme under the Canadian Environmental Protection Act (Meek et al., 1994) based on the IARC ranking scheme. CEPA's scheme consists of more categories and subcategories and is not very compatible with those of IARC and US EPA. CEPA distinguishes between genotoxic and non-genotoxic carcinogens, and gives the latter group a lower ranking.

Some US states, including California, have their own rankings. A comparison of the key ranking schemes is summarized in table A2-4 below.

**Table A2-4: Comparison of the Three Major Cancer Classification Schemes**

| Strength/Type of Evidence | Weight of Evidence Classification | | |
|---|---|---|---|
| | US EPA[1] | IARC[2] | CEPA[3] |
| Sufficient/Strong Human Evidence | A | 1 | I |
| Limited Human + Sufficient Animal Evidence | B1 | 2A | III |
| Some Human, Limited Animal Evidence | B2 | 2B | II |
| Weak Evidence from Human and Animal Data | C | (2B) | III |
| Little Evidence for or Against Carcinogenicity | D | 3 | VI |
| Good Evidence for Absence of Carcinogenicity | E | 4 | V |

1. US EPA, 1986; 2. IARC Monographs website, 2001; 3. Meek et al., 1994.

The route of exposure is an important issue that has to be considered in determining the basis of the cancer classification. Some metals appear to be carcinogenic when inhaled. Although they may have other toxic effects when they are taken up by another route, the evidence for carcinogenicity via these other routes is either absent or not very strong. Most cancer ranking schemes do not provide separate ranking for each route of exposure, although some information may be provided in the text accompanying the ranking. Table A2-5 presents the original ranking by the three agencies for the selected contaminants. For these substances, the carcinogenicity ranking describes the health impact resulting from inhalation exposure, but except for arsenic, does not describe the impact resulting from oral exposure.

**Table A2-5: Cancer Classification by Inhalation and/or Oral Route**

| Substance | General ranking | | |
|---|---|---|---|
| | US EPA[1] | IARC[2] | CEPA[3] |
| Arsenic | A (oral & inhalation) | 1 (oral & inhalation) | I (oral & inhalation) |
| Beryllium | B1 (inhalation) | 2A (inhalation) | NA |
| Cadmium | B1 (inhalation) | 1 (inhalation) | II (inhalation) |
| Nickel | | | |
| Metallic | NA | 2B (inhalation) | VI |
| Soluble Salts | NA | 1 (inhalation) | 1 (inhalation) |
| Insoluble Dusts | A (inhalation) | 1 (inhalation) | I (inhalation) |
| 1. US EPA IRIS, 1998; 2. IARC Monographs, 2001; 3. Health Canada, 1996a. | | | |

**Types and Sites of Cancer**

Different carcinogens have a tendency to induce tumours at different sites and different cancer types. Table A2-6 below summarizes the site and the type of tumour induced by the selected contaminants. The list is not necessarily complete and only the best documented tumours are included in the table. Note that for some contaminants, the site and the type of tumour depend on the route of exposure.

**Table A2-6: Sites and Types of Tumours**

| Substance | Cancer Types | Reference |
|---|---|---|
| Arsenic | skin, lung and other internal cancers | US EPA IRIS, 1998b; IARC, 1998; CEPA, 1996 |
| Beryllium | lung cancer | US EPA IRIS, 1998c; IARC, 1997a; CEPA, 1996 |
| Cadmium | lung cancer | US EPA IRIS, 1998d; IARC, 1997b; CEPA, 1996 |
| Nickel | nasal and lung cancer | US EPA IRIS, 1998f; IARC, 1990; CEPA, 1996 |

Carcinogenic compounds, that act by damaging DNA, are generally considered to work through a non-threshold mechanism which means that an adverse effect is assumed to occur at any level. Any exposure to a carcinogen is considered to be associated with some level of risk. At very low doses, the probability that an adverse effect (cancer) will occur is extremely small. The probability of developing cancer increases as the dose increases. Incremental increases in life time cancer risk are estimated by comparing the established potency for each compound with the calculated CDI for that compound. In addition, potential cancer risks from inhaling airborne metals can be assessed by comparing the annual average concentrations with inhalation unit risk factors from various agencies (Table 3.2).

**Carcinogenic Potency**

Carcinogenic potency by inhalation and oral routes is summarized in tables A2-7 and A2-8.

**Table A2-7: Inhalation Potency of Selected Metals of Concern, Expressed as Unit Risks ($\mu g/m^3$)$^{-1}$ (The recommended values are underlined)**

| | Sources | | |
|---|---|---|---|
| Substance | US EPA[1] | WHO[2] | CEPA[3] |
| Arsenic | 4.3 X $10^{-3}$ | 1.5 X $10^{-3}$ | 6.4 X $10^{-3,(4)}$ ($TC_{05} = 7.8$) |
| Beryllium | $\underline{2.4\ \text{X}\ 10^{-3}}$ | NA | NA |
| Cadmium | $\underline{1.8\ \text{X}\ 10^{-3}}$ | NA | 9.8 X $10^{-3,(4)}$ ($TC_{05} = 5.1$) |
| Nickel | | | |
| Soluble Salts | - | - | 7.1 X $10^{-4\,(4)}$ ($TC_{05} = 70$) |
| Nickel Refinery Dust | $\underline{2.4\ \text{X}\ 10^{-4}}$ | 3.8 X $10^{-4}$ | 1.25 X $10^{-3\,(4)}$ ($TC_{05} = 40$) |
| 1. US EPA IRIS, 1998; 2. WHO, 2000; 3. Health Canada, 1996a; 4. Calculated from $TC_{05}$ value reported by Health Canada (1996a) (unit risk = $0.05/TC_{05}$). | | | |

**Table A2-8: Oral Potencies of Selected Metals of Concern, Expressed as Slope Factors ($\mu g/kg/day$)$^{-1}$**

| | Sources | | |
|---|---|---|---|
| Substance | US EPA[1] | WHO[2] | CEPA[3] |
| Arsenic | 1.5 X $10^{-3}$ | 1.5 X $10^{-3}$ | 2.8 X $10^{-3}$ |
| Beryllium | NA | NA | NA |
| Cadmium | NA | NA | NA |
| Nickel | | | |
| Soluble salts | NA | NA | NA |
| Nickel refinery dust | NA | NA | NA |
| 1. US EPA IRIS, 1998; 2. WHO, 1996, 1998; 3. Health Canada, 1996a; 4. NA = Not Applicable. | | | |

The US EPA is a reliable source of estimates of carcinogenic potency for numerous chemicals.

The US EPA expresses carcinogenic potencies as cancer slope factors (*Risk per (µg/kg body weight-day)* ) or as a *Unit Risk (UR* $(\mu g/m^3)^{-1}$*)* for inhalation exposures or *(UR* $(\mu g/L)^{-1}$*)* for exposures to chemicals in drinking water. The slope factor is defined by the US EPA as;

> *An upper-bound on a maximum likelihood estimate developed from dose-response data using one of several models Incorporating low-dose linearity.*

The Unit Risk is defined as;

> *The upper-level increased likelihood that an individual will develop cancer when exposed to a chemical over a life-time at a concentration of 1 µg/L in drinking water or 1* $\mu g/m^3$ *in air for a continuous inhalation exposure.*

Health Canada provides cancer potency estimates as Tumorigenic Doses ($TD_{05}$) and Tumorigenic Concentrations ($TC_{05}$). These values represent life-time exposure levels that would result in cancers in 5% of the population.

### A2-1.3 Dermal Exposure Limits

There are no dermal exposure limits for the metals of concern in Rodney Street community soils. US EPA (1989, 1992) provides limited guidance on a) determining the relative contribution of the dermal route of exposure and its importance to total exposure, and b) route-to-route extrapolation of exposure limits from another route of exposure (usually oral) to a dermal exposure limit. The approach described involves calculating dermal exposures as absorbed doses, which are compared to an oral exposure limit also expressed as an absorbed dose. Information on the uptake and absorption of the chemical following oral and dermal exposure is required. In addition, the toxicological endpoint should be similar for both routes of exposure. Situations where the dermal route causes an endpoint through direct action on the skin would make route-to-route extrapolation from the oral exposure limit inappropriate. For the metals of concern:

a) estimated dermal intakes from exposure to metals in Rodney Street community soils were less than 1% of the total estimated metal intake from all pathways indicating that this exposure route was not significant. An exception to this was the dermal exposure estimate for antimony which was about 2% to 4% of the total exposure;

b) lead, cadmium, nickel and cobalt are known skin sensitizers and can cause irritation under some conditions. In terms of adverse effect endpoints following systemic absorption, there is no evidence suggesting significantly different toxicological sequelae following absorption from either dermal or oral routes.

Based on a) and b), no adjustments were made to the dermal uptake estimates and these were combined with the oral intake estimates and evaluated using oral exposure limits.

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## A2-2 Toxicological Profile for Antimony

Antimony is a naturally occurring metal that is used in various manufacturing processes. It is generally found as a sulphide or oxides. The natural sulphide of antimony was known and used in Biblical times as medicine and as a cosmetic. The most important use of antimony metal is as a hardener in lead for storage batteries. The metal also finds applications in solders and other alloys. Antimony trioxide is the most important of the antimony compounds and is primarily used in flame-retardant formulations. These flame retardant applications include such markets as children's clothing, toys, aircraft and automobile seat covers.

### A2-2.1 Pharmacokinetics

Exposure to antimony may be via inhalation, oral and dermal routes (ATSDR, 1990). Antimony is sparingly absorbed following ingestion or inhalation (Felicetti et al., 1974; Gerber et al., 1982; US EPA IRIS, 1998a,b). Both gastrointestinal and pulmonary absorption are a function of compound solubility. Trivalent antimony is more readily absorbed than pentavalent forms. Antimony is transported in the blood. Antimony is not metabolized but may bind to macromolecules and react covalently with sulfhydryl and phosphate groups (ATSDR, 1990). Excretion of antimony is primarily via the urine and feces (Cooper et al., 1968; Ludersdorf et al., 1987; ATSDR, 1990).

### A2-2.2 Toxicology

#### A2-2.2.1 Non-Cancer Effects

Acute oral exposure of humans and animals to high doses of antimony or antimony-containing compounds (antimonials) may cause gastrointestinal disorders (vomiting, diarrhea), respiratory difficulties, and death at extremely high doses (Bradley and Frederick, 1941; Beliles, 1979; ATSDR, 1990). Subchronic and chronic oral exposure may affect hematologic parameters (ATSDR, 1990). Long term exposure to high doses of antimony or antimonials has been shown to adversely affect longevity in animals (Schroeder et al., 1970). Limited data suggest that prenatal and postnatal exposure of rats to antimony interferes with vasomotor responses (Marmo et al., 1987; Rossi et al., 1987).

Acute occupational exposure may cause gastrointestinal disorders (probably due to ingestion of airborne antimony) (ATSDR, 1990). Exposure of animals to high concentrations of antimony and antimonials (especially stibine gas) may result in pulmonary edema and death (Price et al., 1979). Long term occupational exposure of humans has resulted in electrocardiac disorders, respiratory disorders, and possibly increased mortality (Renes, 1953; Breiger et al., 1954). Antimony levels for these occupational exposure evaluations ranged from 2,200 to 11,980 µg Sb/m$^3$. Based on limited data, occupational exposure of women to metallic antimony and several antimonials has reportedly caused alterations in the menstrual cycle and an increased incidence of spontaneous abortions (Belyaeva, 1967). Reproductive dysfunction has been demonstrated in rats exposed to antimony trioxide (Belyaeva, 1967).

No data were available indicating that dermal exposure of humans to antimony or its compounds results in adverse effects. Eye irritation due to exposure to stibine gas and several antimony oxides has been reported for humans (Stevenson, 1965; Potkonjak and Pavlovich, 1983).

#### A2-2.2.2 Cancer Effects

The US EPA has not evaluated antimony or antimonials for carcinogenicity. IARC (1989) has classified antimony trioxide as possibly carcinogenic to humans (Group 2B) by inhalation. Antimony trisulphide was not classifiable as to its carcinogenicity to humans (Group 3) (IARC, 1989).

#### A2-2.2.3 Susceptible Populations

No studies were located regarding unusual susceptibility of any human sub-population to antimony. A susceptible population will exhibit a different or enhanced response to antimony than will most persons exposed to the same level of antimony in the environment. Reasons include genetic make-up, developmental stage, health and nutritional status, and chemical exposure history. These parameters result in decreased function of the detoxification and excretory processes (mainly hepatic and renal) or the pre-existing compromised function of target organs. For these reasons the elderly with declining organ function and the youngest of the population with immature and developing organs are expected to be generally more vulnerable to toxic substances than healthy adults (ATSDR, 1992).

### A2-2.3 Current Exposure Limits

#### A2-2.3.1 Oral Exposure Limits

The US EPA (US EPA IRIS, 1998a - oral RfD assessment last revised 1991) has calculated subchronic and chronic oral reference doses (RfDs) of 0.4 µg/kg-day based on decreased longevity and alteration of blood chemistry in rats chronically exposed to potassium antimony tartrate in the drinking water (5 ppm equivalent to 350 µg Sb/kg-day) (Schroeder et al., 1970). More recently, the NRC has proposed an oral RfD for antimony trioxide of 200 µg/kg-day based on increases in serum enzymes and liver weight in female rats in a recent study conducted by Hext et al., 1999 (NRC, 2000). Because there is an inadequate toxicity database, the NRC's confidence in this derived RfD is low to medium. Use of the US EPA's RfD is a more conservative approach.

#### A2-2.3.2 Inhalation Exposure Limits

The US EPA (US EPA IRIS, 1998b - inhalation RfC assessment last revised 1995) has calculated a reference concentration for chronic inhalation exposure (RfC) of 0.2 µg/m$^3$ based on pulmonary toxicity and chronic interstitial inflammation in a one year inhalation toxicity study in rats exposed to antimony trioxide (Newton et al., 1994). This RfC was also proposed by the NRC (NRC, 2000).

### A2-2.3.3 Selection of Exposure Limits

The exposure limits used to assess the potential risks associated with ingestion and inhalation exposures to antimony are summarized in Table A2-9.

**Table A2-9: Selected Exposure Limits for Antimony**

| Route of Exposure | Exposure Limit | Toxicological Basis | Source Agency |
|---|---|---|---|
| Non-Cancer Effects | | | |
| Ingestion | 0.4 µg/kg-day | decreased longevity and altered blood chemistry in rats | US EPA IRIS, 1998a |
| Inhalation | 0.2 µg /m$^3$ | pulmonary toxity in rats | NRC, 2000; US EPA IRIS, 1998b |
| Dermal Contact | - | - | - |
| Cancer Effects | | | |
| Ingestion | N.A.[1] | - | - |
| Inhalation | N.A. | - | - |
| Dermal Contact | N.A. | - | - |

1. Not Applicable

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## A2-3 Toxicological Profile for Arsenic

Arsenic (As) is a brittle, gray metal that tarnishes in air. It is a natural component of the earth's crust and occurs in small amounts in rock, soil, water and underwater sediments. It is commonly found in combination with sulphur and iron in minerals such as arseno-pyrite. Arsenic is used mainly to preserve wood and to control insects and weeds.

Elemental arsenic is not soluble in water; calcium arsenate, and calcium arsenites are sparingly soluble in water; the remaining arsenicals are soluble in water. Arsenic, arsenic pentoxide, arsenic trioxide, the calcium arsenites, lead arsenate, and potassium arsenate are soluble in various acids (ATSDR, 1993).

### A2-3.1 Pharmacokinetics

The oral bioavailability of arsenic compounds is dependent on the chemical species and on the matrix (e.g., soil or dust) in which it is administered. Based on published literature, the absorption of water-soluble inorganic arsenic compounds in an aqueous solution is about 95 percent (ATSDR, 1993). For soil and house dust impacted by operating smelters containing arsenic the oral bioavailability in Cynomolgus monkeys is about 14 and 19 percent respectively (Freeman et al., 1995). The bioavailability of inorganic arsenic for exposure via inhalation would be in the range of 30 – 34 percent (ATSDR, 1993). Dermal absorption through human skin *in vitro* ranged from 0.8 to 1.9 percent (Wester et al., 1993).

Distribution of arsenic within the body is affected by the route through which exposure occurs. Given sufficient time for equilibration, arsenic generally tends to be evenly distributed amongst tissues within the body. The interaction of arsenic with various tissues is dependent on the chemical form of the arsenic. The primary pathway of elimination of inorganic arsenic is excretion via the urine. Because of the importance of urinary excretion as the primary route of elimination of arsenic, concentrations of arsenic compounds in the urine is considered to be a reliable index of recent exposure to arsenic (ATSDR, 1993).

### A2-3.2 Toxicology

#### A2-3.2.1 Non-Cancer Effects

There are numerous studies that have looked at human exposures to inorganic arsenic in the air, but there are no reports of fatalities associated with short term occupational exposures to arsenic levels as high as 100 mg As/m$^3$ (ATSDR, 1993).

Inhalation exposures to inorganic arsenic dusts in the workplace have been reported to cause irritation of the nose and throat, laryngitis, bronchitis and cases of very high exposures have been reported to result in perforation of the nasal septum (ATSDR, 1993). However, respiratory effects have not been noted at exposure levels that range between 0.1 and 1.0 mg/m$^3$ (ATSDR, 1993). There is some limited evidence of respiratory tract effects following oral exposure to inorganic arsenic, but this is thought to be a secondary effect that is due to the vascular damage which results from the ingestion of arsenic (ATSDR, 1993).

There is limited and equivocal epidemiological evidence that suggests that inhalation exposures to arsenic trioxide dust may result in cardiovascular effects. However, there are a number of studies that indicate that oral exposures to inorganic arsenic can lead to serious damage of the cardiovascular system (ATSDR, 1993). Both acute and long-term exposures can result in myocardial depolarization and cardiac arrhythmias. Long term exposures to low levels of arsenic can also result in damage to the vascular system, characterized by a progressive loss of circulation in the hands and feet (ATSDR, 1993). In areas of Taiwan, with elevated levels of arsenic in the drinking water, evidence of circulatory effects related to arsenic exposures were seen at a dose of approximately 0.014 mg As/kg-day (ATSDR, 1993).

There are several studies that have indicated that inhalation exposures to inorganic arsenic can lead to a number of neurological effects in humans, including; peripheral neuropathy of sensory and motor neurons that are manifested as numbness, loss of reflexes and muscle weakness. In extreme cases, frank encephalopathy including, hallucinations and memory loss have been reported (ATSDR, 1993). These effects generally cease once exposures have ended (ATSDR, 1993).

Acute effects of oral arsenic exposure include vomiting, nausea, diarrhea, gastrointestinal haemorrhage and death. There are a large number of cases of human fatalities following the ingestion of inorganic arsenicals. In most cases, the doses resulting in death have been difficult to quantify. However, two reports, indicate that doses ranging between 1 and 22 mg As/kg body weight per day (mg/kg-day) have resulted in death. Although similar effects are often seen with long-term exposures to lower doses of arsenic, effects are not generally reported at doses lower than 0.01 mg As/kg-day (ATSDR, 1993).

There are a large number of studies that indicate that the acute ingestion of large amounts of inorganic arsenic can cause a number of injuries to the nervous system including; headache, lethargy, mental confusion, hallucination, seizures and in extreme cases, coma (ATSDR, 1993). Chronic exposures to lower levels of arsenic, ranging between 0.019 and 0.5 mg/kg-day, are typically characterized by a peripheral neuropathy similar to that seen with inhalation exposures. Neurological effects have not been detected in populations chronically exposed to arsenic levels of less than 0.01 mg/kg-day (ATSDR, 1993).

A number of hematological effects including anemia and leukopenia have been reported in humans as a result of acute, intermediate and chronic oral exposures to arsenic (ATSDR, 1993). These effects are usually not seen in persons exposed to levels of arsenic lower than 0.07 mg/kg-day (ATSDR, 1993).

Oral exposures to inorganic arsenic have been reported to cause several toxic effects in the liver including, elevated levels of hepatic enzymes in the blood, portal tract fibrosis and swelling of the liver (ATSDR, 1993). These effects are generally seen in cases where chronic exposures range between 0.019 to 0.1 mg/kg-day (ATSDR, 1993). It has been suggested by several researchers that these effects are secondary to the damage of hepatic blood vessels resulting from the damaging effects that inorganic arsenic has on the circulatory system. However, there is insufficient clinical information available to confirm this (ATSDR, 1993).

There is little clinical evidence of renal damage following oral exposures to inorganic arsenic compounds (ATSDR, 1993). A few cases of renal failure have been reported in cases of arsenic poisoning, but this is felt to be due to fluid imbalances of vascular damage caused by arsenic, and not directly attributable to arsenic (ATSDR, 1993).

The most common dermal effect associated with the ingestion of inorganic arsenic is the development of a pattern of skin changes which include; hyperkeratosis, the development of hyperkeratotic warts, areas of hyperpigmentation and hypopigmentation (ATSDR, 1993). Numerous studies have shown that dermal effects are common in humans exposed to inorganic arsenic levels that range between 0.01 and 0.1 mg As/kg-day. These studies have also demonstrated that, below a dose level of 0.01 mg As/kg-day, dermal effects are not reported (ATSDR, 1993).

### A2-3.2.2 Cancer Effects

There is sufficient convincing epidemiological evidence to show that inhalation exposure to inorganic arsenic can increase the risk of developing lung cancer. Many studies provide only qualitative evidence of an association between the duration of and/or level of exposure to arsenic and the increase in the rate of lung cancer. There is sufficient epidemiological information available from occupational studies for the US EPA to develop cancer potency estimates for inhalation exposures to inorganic arsenic (US EPA IRIS, 1998 - carcinogenicity assessment last revised 1998). Health Canada (1996) classified inorganic arsenic compounds as Group I (carcinogenic to humans).

There are a large number of epidemiological studies that provide convincing evidence that the ingestion of inorganic arsenic increases the risk of developing skin cancer. The most common effect is the development of squamous cell carcinomas. Basal cell carcinomas also occur. In the majority of cases, skin cancer only develops after prolonged exposure (ATSDR, 1993). There is sufficient human epidemiological data available for the US EPA to develop estimates of cancer risk associated with oral exposure to inorganic arsenic (US EPA IRIS, 1998 - carcinogenicity assessment last revised 1998).

### A2-3.2.3 Susceptible Populations

No studies were located regarding unusual susceptibility of any human sub-population to arsenic. A susceptible population will exhibit a different or enhanced response to arsenic than will most persons exposed to the same level of arsenic in the environment. Reasons include genetic make-up, developmental stage, health and nutritional status, and chemical exposure history. These parameters result in decreased function of the detoxification and excretory processes (mainly hepatic and renal) or the pre-existing compromised function of target organs. For these reasons the elderly with declining organ function and the youngest of the population with immature and developing organs are expected to be generally more vulnerable to toxic substances than healthy adults (ATSDR, 1993).

### A2-3.3 Current Exposure Limits

#### A2-3.3.1 Oral Exposure Limits

The US EPA IRIS (1998 - oral RfD assessment last revised 1993) calculated an oral RfD of 0.3 µg As/kg-day based on epidemiological studies of chronic exposure to arsenic through drinking water. This limit was selected for non-carcinogenic effects.

Arsenic exposure via the oral route was considered to be carcinogenic to humans, based on the incidence of skin cancers in epidemiological studies examining human exposure through drinking water. The cancer slope factor of 0.0015 $(\mu g\ As/kg\text{-}day)^{-1}$ and corresponding risk specific dose (RSD) of 0.00067 µg As/kg-day are based on an acceptable risk level of one-in-one million.

WHO (1996) calculated an arsenic in drinking water risk of $10^{-5}$ $(\mu g/\ L)^{-1}$ based on prevalence of skin cancer in Taiwanese studies and the US multistage model.

Health Canada (Health Canada, 1996; CEPA, 1996) developed a $TC_{05}$ of 840 µg/L for drinking water based on the Taiwanese studies and the US EPA's 1988 model (US EPA 1988, as cited in CEPA, 1996) adjusted for Canadian ingestion volumes.

#### A2-3.3.2 Inhalation Exposure Limits

The US EPA (US EPA IRIS, 1998 - carcinogenicity assessment last revised 1998) calculated an inhalation unit risk for arsenic of 0.0043 $(\mu g/m^3)^{-1}$ based on epidemiological studies of lung cancer in workers at arsenic smelters.

WHO (2000) calculated an inhalation unit risk for arsenic of 0.0015 $(\mu g/m^3)^{-1}$ based on epidemiological studies of lung cancer in workers at arsenic smelters in Sweden and the USA.

Health Canada (1996) developed a $TC_{05}$ of 7.8 $\mu g\ /m^3$ based on occupational exposure data at the Anaconda copper smelter in Montana and a relative risk model.

#### A2-3.3.3 Selection of Exposure Limits

See discussion in Section 5.7 (Main report - Part B).

### A2-3.4 Arsenic References

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## A2-4 Toxicological Profile for Beryllium

Beryllium (Be) is a hard, grayish, odorless metal. The element occurs naturally as a chemical component of certain rocks, coal and oil, volcanic dust, and soil. Two kinds of mineral rocks, bertrandite and beryl, are mined commercially for the recovery of beryllium (ATSDR, 1993). Beryllium is used in beryllium-copper alloys, in microelectronics, in aerospace technology, as a solid-propellant in rocket fuels (Lewis, 1993), in aircraft brakes, in X-ray windows, and in neutron reflectors (Ashford, 1994).

### A2-4.1 Pharmacokinetics

Inhaled beryllium is absorbed through the lungs, however insufficient data are available to determine the rate and extent of absorption. The biological half-life of beryllium in serum is estimated to be between two to eight weeks.

Toxicity through oral exposure is not very likely since animal studies show that beryllium is not efficiently absorbed through the gastrointestinal tract. Soluble salts are precipitated by reaction with proteins in the alimentary tract (Browning, 1969). No human data are available regarding the absorption of beryllium after oral exposure.

Beryllium does not appear to be absorbed through intact skin as exposed workers demonstrated skin rashes and ulcerations only when the skin was cut accidently.

### A2-4.2 Toxicology

#### A2-4.2.1 Non-Cancer Effects

Inhalation of high concentrations of soluble beryllium compounds has caused pneumonia in occupationally exposed workers. Chronic inhalation exposure to somewhat lower concentrations can lead to an obstructive lung disease known as chronic beryllium disease (CBD). Chronic beryllium disease is caused by genetically regulated cell-mediated immune responses (US EPA IRIS, 1998; Chang, 1996).

Swallowing beryllium has not been reported to cause effects in humans because very little beryllium can move from the stomach and intestines into the bloodstream. No human data are available regarding ingestion of beryllium, however animal studies show lesions on the stomach as well as the small and large intestines as the result of ingestion of beryllium sulphate in the diet.

Skin lesions have been reported in a few individuals occupationally exposed to beryllium. Skin ulceration occurred only if the skin had been accidently cut.

#### A2-4.2.2 Cancer Effects

Several epidemiological studies show an increase incidence of lung cancer deaths amongst workers employed at beryllium factories (ATSDR, 1993). However, historical exposure levels were not reported so no correlation could be drawn between the incidence of lung cancer deaths and beryllium exposure.

The United States Environmental Protection Agency classifies inhaled beryllium and beryllium compounds as a probable human carcinogen (Group B1) based on limited evidence for humans and sufficient data for animals (US EPA IRIS,1998 - carcinogenic assessment last revised 1998). The United States Environmental Protection Agency also indicates that there are no studies on the potential carcinogenicity of ingested beryllium for humans and that the available animal studies do not indicate any adverse effects (US EPA IRIS, 1998 - carcinogenic assessment last revised 1998). The United States National Toxicology Program classifies beryllium and compounds as reasonably anticipated carcinogens (NTP, 2001).

The International Agency for Research on Cancer has classified beryllium and beryllium compounds as carcinogenic to humans (Group 1) based on sufficient animal and human data.

### A2-4.2.3 Susceptible Populations

A genetic predisposition for a human leukocyte antigen (HLA) class II may make some individuals more susceptible to chronic beryllium disease. Other factors which may increase susceptibility to beryllium are lowered adrenal gland or liver function.

## A2-4.3 Current Exposure Limits

### A2-4.3.1 Oral Exposure Limits

The United States Environmental Protection Agency has developed an oral reference dose of 2.0 µg/kg-day for beryllium (US EPA IRIS, 1998 - oral R*f*D assessment last revised 1998). The reference dose is based on a benchmark dose derived from dose response modelling of data for a study of lesions on the small intestines of dogs (Morgareidge et al., 1976). A benchmark dose is the dose at the 95% confidence interval of a dose-response model and corresponds to a 10% increase in effects (stomach lesions) in comparison to the control population. An uncertainty factor of 300 (ten for interspecies differences, ten for differences in human populations and three for database deficiencies) was applied to the benchmark dose to determine the reference dose.

ATSDR has developed a minimal risk level (MRL) for beryllium based on the same dog study (Morgareidge et al., 1976) of 1.0 µg beryllium/kg-day. The MRL was determined by applying an uncertainty factor of 100 to the no-observed-adverse-effect level (NOAEL) at 100 µg beryllium/kg-day.

### A2-4.3.2 Inhalation Exposure Limits

The US EPA (US EPA IRIS, 1998 - inhalation R*f*C assessment last revised 1998) has developed an inhalation R*f*C of 0.02 $\mu g/m^3$ based on beryllium sensitization and progression to chronic beryllium disease in beryllium workers (Kreiss et al., 1996) and the Eisenbud et al., (1949) study of community residents living near a beryllium plant.

The US EPA (US EPA IRIS, 1998 - carcinogenic assessment last revised 1998) has developed an inhalation unit risk of 0.0024 $(\mu g/m^3)^{-1}$ based on lung cancer mortality in male beryllium manufacturing workers (Wagoner et al., 1980). The air concentration at the $10^{-5}$ and $10^{-6}$ life-time cancer risk levels are 0.004 $\mu g/m^3$ and 0.0004 $\mu g/m^3$, respectively.

### A2-4.3.3 Selection of Exposure Limits

The estimates of the carcinogenic potencies of inhaled beryllium and non-cancer effects of inhaled and ingested beryllium, developed by the US EPA will be used to assess potential human health risks associated with exposure to beryllium at this site. The selected exposure limits established by the US EPA and the health effects upon which they are based are summarized below (Table A2-10).

**Table A2-10: Selected Exposure Limits for Beryllium**

| Route of Exposure | Exposure Limit | Toxicological Basis | Source Agency |
|---|---|---|---|
| Non-Cancer Effects | | | |
| Ingestion | 2 $\mu g/kg$-day | intestinal lesions in dogs | US EPA IRIS, 1998 |
| Inhalation | 0.02 $\mu g/m^3$ | beryllium sensitization in human populations | US EPA IRIS, 1998 |
| Cancer Effects | | | |
| Ingestion | N/A[1] | - | - |
| Inhalation | $0.0024\ (\mu g/m^3)^{-1}$ | lung cancer in humans | US EPA IRIS, 1998 |

1. Not Applicable

### A2-4.4 Beryllium References

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US EPA IRIS. 1998a. Beryllium and Compounds. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Cincinnati, OH.Online at http://www.epa.gov/iris/index.html. (Accessed Oct. 17, 2001).

Wagoner, J.K., P.F. Infante and D.L. Bayliss. 1980. Beryllium: an etiologic agent in the induction of lung cancer, nonneoplastic respiratory disease, and heart disease among industrially exposed workers. Environ. Res. 21: 15-34.

## A2-5 Toxicological Profile for Cadmium

Cadmium is a natural element that is usually found as a mineral combined with other elements such as oxygen, chloride and sulphur. Cadmium forms both organic and inorganic compounds. It is extracted mostly during the production of other metals, and is used in batteries, pigments, metal coatings and plastics.

### A2-5.1 Pharmacokinetics

Following inhalation, the major site of cadmium absorption in humans is the alveoli of the lung. Human data are not available for absorption in the lung. A kinetic respiratory tree model has been developed to predict cadmium particle deposition in the lung (Nordberg et al., 1985). This model suggests that only 5% of the particles that are greater than 10 µm in diameter will be deposited and that about 50% of the particles less than 0.1 µm will be deposited. The respiratory tree model also predicts that 50 to 100% of the cadmium deposited in the alveoli will be absorbed.

The majority of ingested cadmium tends to pass through the gastrointestinal tract without being absorbed and is excreted in the feces. Absorption of ingested cadmium is influenced by nutritional status, with absorption increased by low intake of calcium, iron, zinc and copper (Nordberg et al., 1985). Absorbed (from the lungs and gastrointestinal tract) cadmium tends to be excreted very slowly and is found in equal proportions in the urine and feces. The main target organ for cadmium following ingestion is the kidney. The half life of cadmium in the human body is very long. An estimated half life for cadmium in the kidney ranges from 6 to 38 years and the liver from 4 to 19 years (ATSDR, 1998). The placenta may act as a partial barrier to fetal cadmium exposure.

Cadmium is not metabolized, rather it binds to proteins and other molecules. In particular it binds to the protein, albumin in the bloodstream which transports cadmium to the liver. Once cadmium enters the liver it becomes bound to another protein called metallothionein and is released to the bloodstream. The metallothionein bound cadmium is then filtered by the kidney glomerulus and is then reabsorbed by the proximal tubule cells. Lysozymes degrade the cadmium-metallothionein complex and cause free cadmium to be released in the kidney. The free cadmium initiates the synthesis of metallothionein in the proximal tubule cells and can also cause damage to the kidneys in excessive amounts.

There is currently not enough information to determine the potential absorption of cadmium via the dermal route of exposure (ATSDR, 1998). Based on the limited information it appears that very little cadmium is absorbed through the skin.

### A2-5.2 Toxicology

Cadmium and cadmium compounds possess moderately acute toxicity via both ingestion and inhalation. Cadmium is slowly excreted by the body, and therefore bioaccumulates in humans. Chronic cadmium poisoning can be associated with both inhalation and ingestion.

### A2-5.2.1 Non-Cancer Effects

Based on studies of cadmium production workers, the route of entry for cadmium with the most immediate health effects is inhalation of fumes or dust. Localized health effects caused by cadmium exposure include irritation to the respiratory tract and to the mucous membrane lining of the inner surface of the eyelid. This is often accompanied by dyspnea (severe difficulty in breathing) and general weakness. Troubled breathing may become more pronounced as pulmonary edema and tracheobronchitis develop. The most common result of acute systemic cadmium exposure is emphysema, but in some instances, mortality may occur. Prolonged exposure may also result in anosmia (loss of sense of smell) and discoloration of the teeth.

Ingestion of high acute doses of cadmium may cause gastrointestinal effects such as nausea, vomiting, and abdominal pain (Nordberg et al., 1973). Cadmium causes kidney damage, particularly to the proximal renal tubules in the early stages and, as the disease progresses, or the dose increases, glomerular damage is also observed. Renal dysfunction has been demonstrated to be a consequence of chronic low level exposure to both inhaled and ingested cadmium (Bernard et al., 1994).

Chronic cadmium exposure coupled with poor nutrition can lead to changes in the way which the kidney metabolizes vitamin D. This can result in painful bone diseases such as osteomalacia and osteoporosis, mainly in women. There is limited data to suggest that cadmium exposures in pregnant women may result in decreased birth weight in their babies.

Epidemiologic studies have found an association between cadmium exposure and osteoporosis. Findings in a study on workers exposed to cadmium for up to five years suggest dose-response relationships between cadmium dose and bone mineral density and between cadmium dose and osteoporosis (Järup et al., 1998). In a study on residents living within known proximities to zinc smelters, low to moderate environmental exposure to cadmium was associated with skeletal demineralization and incidence of fractures and height loss (Staessen et al., 1999).

Cadmium appears to have a relatively low dermal toxicity based on studies that showed that workers who were occupationally exposed to high levels of cadmium dust, did not report any dermal effects. Cadmium does not appear to cause sensitization by repeated dermal contact.

### A2-5.2.2 Cancer Effects

Epidemiological studies demonstrate increased incidence of lung cancer in workers exposed to cadmium via the inhalation route, however, the studies did not control for factors such as smoking and simultaneous exposures to other metals so the causal relationship is somewhat controversial. Oral exposure to cadmium has not been associated with cancer in humans or animals.

The United States Environmental Protection Agency has classified cadmium as a probable human carcinogen (Group B2) when inhaled, based on limited human and sufficient animal data (US EPA IRIS, 1998 - carcinogenicity assessment last revised 1992). Health Canada (Newhook et al., 1994) has classified cadmium as a Group II carcinogen.

### A2-5.2.3 Susceptible Populations

Populations which may be unusually susceptible to cadmium exposure are those with a genetic predisposition to lower inducibility of metallothionein, the enzyme which sequesters cadmium. Dietary deficiencies which lead to depleted levels of calcium or iron in individuals may result in increased absorption of cadmium from the gastrointestinal tract. Infants and children may have increased uptake of cadmium via the gastrointestinal tract and higher concentrations of cadmium in the bone.

### A2-5.3 Current Exposure Limits

### A2-5.3.1 Oral Exposure Limits

ATSDR (1998) has developed a chronic oral minimum risk level of 0.2 μg/kg-day for cadmium. The chronic MRL is derived from a NOAEL of 2.1 μg/kg-day from a study of cadmium accumulation in the kidneys of Japanese farmers living in an area of Japan with highly elevated cadmium levels. An uncertainty factor of ten was used to account for variability in the human population.

The United States Environmental Protection Agency has developed oral reference doses for cadmium for food and water. The oral reference dose for food is 1.0 μg/kg-day and for water is 0.5 μg/kg-day (US EPA IRIS, 1998 - oral R*f*D assessment last revised 1994). The highest cadmium level in the human kidney which does not produce proteinuria (excretion of low weight molecular proteins into the urine) has been determined to be 200 μg cadmium/g of wet kidney cortex. A toxicokinetic model was used to determine the level of chronic oral exposure that would result in a cadmium kidney concentration of 200 μg cadmium/g of wet kidney cortex. The toxicokinetic model assumes that 0.01% of the body cadmium kidney burden is eliminated daily and that absorption of cadmium from food and water are 2.5% and 5% respectively. A No-Observed-Adverse-Effect Level (NOAEL) for chronic cadmium exposure was determined to be 5.0 and 10 μg/kg-day. An uncertainty factor of ten to account for human variability was applied to the NOAELs to develop the reference doses for food and water.

Joint FAO/WHO Expert Committee on Food Additives (WHO, 1993) proposed that the total daily intake of cadmium should not exceed 1 μg/kg body weight/day. This intake was designed to keep the cadmium levels in the renal cortex below 50 μg/g, and assumed an absorption rate for dietary cadmium of 5% and a daily excretion rate of 0.005% of body burden (WHO, 1996).

Health Canada has not determined a tolerable daily intake for cadmium (Health Canada, 1996).

### A2-5.3.2 Inhalation Exposure Limits

The US EPA (US EPA IRIS, 1998 - carcinogenicity assessment last revised 1992) has developed an inhalation unit risk of 1.8 x$10^{-3}$ ($\mu g/m^3$)$^{-1}$. This unit risk is based on lung and upper respiratory tract cancers in cadmium production workers (Thun et al., 1985). The air concentration at the $10^{-5}$ life-time cancer risk level (1-in-100,000) is 0.006 $\mu g/m^3$.

The WHO has an annual guideline value (non-cancer) of 0.005 $\mu g/m^3$ (WHO, 2000).

Health Canada has calculated a $TC_{05}$ of 5.1 µg/m3. This $TC_{05}$ is based on lung tumor incidence in an inhalation exposure bioassay with rats exposed to cadmium chloride for 18 months (Takenaka et al., 1983, Oldiges et al., 1984). This $TC_{05}$ was amortized over the standard life-time of a rat, and converted to an equivalent concentration in humans using standard values for breathing volumes and body weights of rats and humans. It can be divided by 5000 to obtain a $10^{-5}$ life-time cancer risk air concentration of 0.001 µg/m$^3$.

### A2-5.3.3 Selection of Exposure Limits

The estimates of the carcinogenic potencies of inhaled cadmium and non-cancer effects of ingested cadmium, developed by the US EPA will be used to assess potential human health risks associated with exposure to cadmium at this site. The selected exposure limits established by the US EPA and the health effects upon which they are based are summarized below (Table A2-11).

**Table A2-11: Selected Exposure Limits for Cadmium**

| Route of Exposure | Exposure Limit | Toxicological Basis | Source Agency |
|---|---|---|---|
| Non-Cancer Effects | | | |
| Ingestion | 1 µg/kg-day | kidney damage in humans | US EPA IRIS, 1998; WHO (JECFA), 1993 |
| Inhalation | N/A[1] | - | - |
| Cancer Effects | | | |
| Ingestion | N/A[1] | - | - |
| Inhalation | 1.8 X $10^{-3}$ (µg/m$^3$)$^{-1}$ | lung cancer in cadmium workers | US EPA IRIS, 1998 |

1. Not Applicable

### A2-5.4 Cadmium References

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WHO (World Health Organization - JECFA). 1993. Evaluation of certain food additives and contaminants: forty-first report of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). WHO, Geneva (WHO Technical Report Series, No. 837).

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## A2-6 Toxicological Profile for Cobalt

Cobalt exists in nature as a brittle hard metal, closely resembling iron and nickel in appearance. It has two valence states (Co(II) and Co(III)), which form numerous organic and inorganic salts. It is alloyed with iron and nickel to make Alnico. Cobalt is used in Stellite alloys, and stainless steel alloys used in jet and gas turbines. Cobalt salts have been used for centuries for the production of brilliant and permanent blue colours in porcelain, glass, pottery and enamel.

Cobalt is an essential nutrient for humans as it is needed to make vitamin $B_{12}$. Vitamin $B_{12}$ is a coenzyme in many biological reactions including the production of red blood cells. Cobalt has, therefore, also been used to treat anemia. As cobalt is an essential element, it is found in most body tissues with the highest concentrations occurring in the liver, kidney and bones.

### A2-6.1 Pharmacokinetics

Inhaled cobalt particles accumulate in the respiratory tract depending on particle size (see section A2-9.2.1.1). From the lungs, cobalt particles either dissolve into the bloodstream or are transferred to the gastrointestinal tract by mucocilliary action and swallowing. Approximately 50% of the cobalt transferred to the gastrointestinal tract is actually absorbed and the rest is eliminated in the feces. About 50 % of the portion of the initial lung burden can remain up to six months after exposure (Foster et al., 1989 as cited in ATSDR, 1992).

Cobalt consumed by the oral route of exposure is absorbed by the gastrointestinal tract. The amount of cobalt absorbed ranges from18 to 97% in humans and is dependent upon the dose and type (form) of cobalt as well as the nutritional status of the individuals involved. Cobalt absorption tends to increase in subjects which have iron deficiencies in their diet. Elimination in the feces is the primary excretion method for oral cobalt exposures.

Absorption of cobalt through intact, or unbroken skin does not generally occur (ATSDR, 1992). However, cobalt may be absorbed through broken or injured skin.

### A2-6.2 Toxicology

#### A2-6.2.1 Non-Cancer Effects

Acute effects of exposure to cobalt-containing dust occupationally are typically inflammation of the nasopharynx. Inhalation of cobalt can affect the respiratory system and if sufficient quantities are inhaled (3μg cobalt/$m^3$), irritation, wheezing, asthma and pneumonia can result. The occupational exposure levels noted here are approximately 10,000 to 100,000 times the typical outdoor air concentration. Individuals can also develop a sensitivity to cobalt if exposed continually in an occupational setting to concentrations of about 7 μg cobalt/$m^3$ and subsequent exposures can result in skin rashes or asthma attacks (ATSDR, 1992).

Oral exposure to cobalt has occurred in humans who consumed beer containing cobalt salts. In the 1960s, cobalt salts were added to beer to improve its foaming qualities. This practice has been discontinued as it led to several deaths amongst heavy beer drinkers (8 to 30 pints per day) who consumed doses ranging from 3 to 10 mg cobalt per day ("beer drinkers cardiomyopathy"). Less serious effects associated with the consumption of beer containing cobalt compounds included nausea, vomiting and diarrhea. Increased production of red blood cells also occurs in humans after oral exposure to cobalt. Decreased uptake of iodine by the thyroid gland has been observed in humans exposed to short term doses of 1000 µg cobalt/kg-day or longer term doses of 540 µg cobalt/kg-day (ATSDR, 1992).

Developmental effects were not observed in babies born to mothers who were taking medication containing cobalt to regulate anemia while pregnant (Holly, 1955 as cited in ATSDR, 1992). Reproductive effects were not observed in the people who died after exposure to high cobalt levels in beer. Some effects have been observed in animals (adverse effects on the testes and increased length of the estrous cycle), however, the significance of these effects for humans is not clear as the cobalt doses used in these studies were much higher than those to which humans are usually exposed.

Contact dermatitis has also been consistently reported as an outcome of acute dermal exposure to cobalt compounds in occupational settings.

### A2-6.2.2 Cancer Effects

Hamsters exposed to cobalt oxide dust did not develop an increased incidence of lung tumours in comparison to the control population. Intramuscular injection of cobalt oxide resulted in the production of tumours in rats but not in mice (Gilman 1962 as cited in ATSDR, 1992). Based on animal data, the International Agency for Research on Cancer (1991) has classified cobalt as 2B; possibly carcinogenic for humans.

There is insufficient evidence to implicate cobalt or cobalt compounds as human carcinogens. Cobalt has not been shown to cause cancer in humans.

### A2-6.2.3 Susceptible Populations

People who are already sensitized to cobalt may be unusually susceptible because subsequent cobalt exposure may trigger an asthma attack. Cobalt sensitization can be determined by cobalt-specific changes to serum antibodies (IgE and IgA).

## A2-6.3 Current Exposure Limits

### A2-6.3.1 Oral Exposure Limits

The recommended daily intake of cobalt as vitamin $B_{12}$ is 2 µg/day for adults and 0.3 µg/day for children less than two years old (Health Canada, 2000).

The US EPA Region III derived an oral *RfD* of 20 µg/kg-day for cobalt based on cobalt intake levels in food (US EPA, 2001). This *RfD* was based on the upper range of average intake for children, that is below the levels of cobalt needed to induce polycythemia in both renally compromised patients. However, the current US EPA IRIS list of chemicals does not include cobalt.

### A2-6.3.2 Inhalation Exposure Limits

An intermediate minimal risk level (MRL) of 0.03 µg cobalt/m$^3$ is proposed by the Agency for Toxic Substances and Disease Registry (ATSDR, 1992). This inhalation R/C is based on a Lowest-Observed-Adverse Effect Level (LOAEL) of 110 µg/m$^3$ (as cobalt sulphate) for squamous metaplasia of the larynx in rats and mice exposed for 13 weeks in the NTP (1991) and Bucher et al., (1990) studies. This dose was adjusted for intermittent exposure, converted to an equivalent concentration in humans, and a safety factor of 1000 was applied.

No regulatory dermal exposure limits for cobalt were identified in the literature reviewed for the current assessment.

### A2-6.3.3 Selection of Exposure Limits

The estimates of the carcinogenic potencies of inhaled cobalt and non-cancer effects of ingested cobalt, developed by the US EPA will be used to assess potential human health risks associated with exposure to cobalt at this site. The selected exposure limits established by the US EPA and the health effects upon which they are based are summarized below (Table A2-12).

**Table A2-12: Selected Exposure Limits for Cobalt**

| Route of Exposure | Exposure Limit | Toxicological Basis | Source Agency |
|---|---|---|---|
| Non-Cancer Effects | | | |
| Ingestion | 20 µg/kg-day | effects in renally compromised patients | US EPA, 2001 |
| Inhalation | 0.03 µg/m$^3$ | squamous metaplasia in rodent larynx | ATSDR, 1992 |
| Cancer Effects | | | |
| Ingestion | N/A[1] | - | - |
| Inhalation | N/A | - | - |

1. Not Applicable

### A2-6.4 Cobalt References

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US EPA Region III. 2001. Risk-Based Concentration Table. US Environmental Protection Agency, Region III, Philadelphia, Penn. http://www.epa.gov/reg3hwmd/risk/riskmenu.htm. (Accessed Oct. 18, 2001).

## A2-7 Toxicological Profile for Copper

Copper is a natural element that is also an essential nutrient for the human body. It is used as a conductive agent in electrical equipment, reducing agent, catalyst, as wire material, and can be found in some pesticides.

Copper can be ingested from drinking water or eating certain foods. Another possible route of exposure includes the inhalation of roadway dust containing copper from the use of car brakes. It could also be ingested from foods that have absorbed it from copper cookware. Copper sulphate is used as a pesticide, fungicide and nutritional supplement in animal feed and fertilizer.

Copper is an essential element for humans and is found widely throughout the body. Adverse health effects can be linked to both copper deficiency as well as excessive copper levels. Copper deficiency is demonstrated by anemia, neutropenia and bone abnormalities, but is rarely observed in clinical situations. Copper is considered essential for the development of structural and enzymatic proteins. Enzymes regulating cellular respiration, free radical detoxification, iron metabolism, neurotransmitter function and synthesis of connective tissue contain copper. Regulation (activation and repression) of gene transcription also requires copper. Copper concentrations are regulated in the body by a process called homeostasis (ATSDR, 1990).

Copper regulates the mechanism which controls its intracellular homeostasis. Copper enters the liver where it is reduced and then complexes with glutathione. Metallothionein is the primary protein to which copper binds and these proteins are involved in the detoxification and binding of excess copper. Copper binds to the transcription factor which causes the production of metallothionein. When cellular copper levels are high then copper will bind to the metallothionein transcription factor causing metallothionein production, thereby detoxifying excess copper concentrations. If cellular copper levels are low, it is unlikely that there will be enough copper to bind to the metallothionein transcription factor, thereby limiting the production of metallothionein so that the copper can be used for metabolism (Gollan et al., 1973).

### A2-7.1 Pharmacokinetics

No studies were found which document absorption, distribution or elimination of copper following inhalation exposure.

Absorption of copper occurs primarily through the gastrointestinal tract. Copper absorption is related to the amount of copper in the diet. For example, when adults were administered a low copper diet (780 µg copper per day), 55.6% of the administered copper was absorbed by the gastrointestinal tract as determined by the use of isotopes. For adults who were administered an adequate dose of copper in their diet (1,680 µg copper per day), 36.3% absorption was observed and for adults with a high daily copper intake (7,530 µg copper per day), only 12.4 % absorption was found. Copper absorption in adults is saturable and the percentage of copper absorbed decreases as the daily intake of copper increases. Total retention of copper increased with dietary intake and appropriate balance was maintained even at the lowest concentration studied (780 µg copper per day). Copper absorption and metabolism decreases as a result of competition with high levels of other metals such as iron and zinc for binding sites on metallothionein. Molybdenum inhibits copper retention.

Recent studies with an isotopic tracer indicate that infants absorb sufficient copper to meet their growth needs (Ehrenkranz, 1989). Infants appear to reduce copper intake at high dietary concentrations by increasing fecal elimination and decreasing absorption.

The liver is the major organ involved in the distribution of copper throughout the body; distribution of copper to other tissues throughout the body occurs through the blood stream. The highest concentrations of copper are found in the brain, kidney, heart, liver and pancreas. Ceruloplasmin (a protein which can bind six to eight Cu(II) atoms) and serum albumin appear to be the major carriers of copper through the bloodstream.

Bile is the major elimination pathway for liver copper as it accounts for approximately 80% of the copper leaving the liver. Pregnancy is associated with increased copper retention likely due to decreased biliary excretion resulting from the hormonal changes which typically occur. Urinary excretion and sweating are minor contributors to copper removal.

The use of topical medications containing copper compounds can increase dermal absorption of copper (Eldad et al., 1995). Components of topical medication such as salicylic acid or phenylbutazone facilitate the transport of copper through the skin.

### A2-7.2 Toxicology

#### A2-7.2.1 Non-Cancer Effects

Inhalation exposure information is limited to studies on factory workers who have been exposed to significantly higher copper air concentrations than the general public. Copper dust is considered a respiratory irritant as factory workers experienced irritation of the mucosal membranes of the mouth, nose and eyes. Metal fume fever has also been observed in workers exposed to high concentrations of fine copper dust in air. Gastrointestinal effects such as nausea, anorexia and occasionally diarrhea were also experienced by factory workers and it is thought that the gastrointestinal effects are primarily due to swallowing a portion of the airborne copper (ie., would be classified as an oral exposure).

Copper is rarely toxic unless very large amounts are ingested. The available toxicity data associated with oral consumption of copper are limited to ingestion of water with very high copper concentrations or suicide attempts involving copper sulphate. Chronic exposure to drinking water containing (dose approximately 60 µg copper/kg-day, which equals a 4,200 µg copper/day for a 70 kg adult) resulted in nausea, vomiting and abdominal pain shortly after consumption of the water. The gastrointestinal difficulties stopped after an alternate water supply was found for the affected persons.

Chronic copper poisoning is very rare, since the capacity for healthy human livers to excrete copper is considerable. Any reports of chronic copper poisoning that do exist involve patients with liver disease.

Developmental effects have not been observed in children of mothers with Wilson's Disease (a metabolic disorder which causes accumulation of copper in the liver) or healthy humans. Developmental toxicity has been found in mice, mink and hamsters who were fed a high copper diet or injected with copper. Reproductive effects have not been observed in human populations exposed to high copper levels. Copper containing intrauterine devices are used as a method of birth control and animal studies have shown that the copper wires contained within these devices are the contraceptive agent.

Dermal exposure to copper can result in allergic contact dermatitis.

### A2-7.2.2 Cancer Effects

The United States Environmental Protection Agency has classified copper and copper compounds in Group D which indicates that they are substances for which inadequate data are available to make a carcinogenicity assessment. Specifically, for copper and copper compounds there are no human carcinogenicity data, animal bioassay data is inadequate and mutagenicity tests are equivocal (US EPA IRIS, 1998 - carcinogenicity assessment last revised 1991).

### A2-7.2.3 Susceptible Populations

Infants and children under one year old are unusually susceptible to copper toxicity because they have not developed the homeostatic mechanism to remove copper from the body. Wilson's Disease is a genetic disorder associated with impaired transport of copper from the liver to the bile, thereby resulting in increased copper concentrations in the liver as they are not able to maintain homeostasis. Another genetic condition which increases the susceptibility to copper toxicity is a deficiency in the enzyme glucose-6-phosphate dehydrogenase. Individuals with liver disease are also susceptible to copper toxicity because of the critical role the liver plays in eliminating copper from the body.

## A2-7.3 Current Exposure Limits

### A2-7.3.1 Oral Exposure Limits

As copper is considered an essential element for humans there are two types of exposure limits that are considered: (a) the minimal daily intake so that a person will not suffer from copper deficiency; and (b) the maximal permissible daily intakes so that a person will not suffer from copper toxicity.

The World Health Organization (WHO, 1998) has determined the minimal daily copper intake for adults to be 20 µg copper/kg-day which is equivalent to 1,400 µg copper per day for the average 70 kg adult. For children, the World Health Organization concluded that the minimal daily copper intake should be 50 µg copper/kg-day (equivalent to 750 µg copper per day for a 15 kg child). The minimal daily copper intake was determined as the amount of copper needed for a child or adult to function properly while accounting for variables such as differences in copper absorption, retention and storage.

The Recommended Dietary Allowance (RDA) for US adults is 900 µg copper/day or about 13 µg/kg-day (IOM, 2001). This RDA is a combination of indicators, including plasma copper and ceruloplasmin concentrations, erythrocyte superoxide dismutase activity and platelet copper concentration in controlled human depletion/repletion studies.

The US Reference Daily Intake (a term which replaces "US RDA") for copper is 2,000 µg/day or about 30 µg/kg/day for adults (US FDA, 1999).

The tolerable upper intake level for US adults is 10,000 µg/day or about 140 µg/kg/day, and is based on protection from liver damage (IOM, 2001).

### A2-7.3.2 Inhalation Exposure Limits

A chronic non-cancer Reference Exposure Level (REL) of 2.4 µg/m$^3$ is listed for copper compounds in the California Air Pollution Control Officers Association Air Toxics "Hot Spots" Program, Revised 1992 Risk Assessment Guidelines. This REL is based on respiratory effects (CAPCOA, 1993). The United States Environmental Protection Agency (US EPA) has not established a Reference Concentration (RfC) for copper compounds (US EPA IRIS, 1998 - inhalation RfC assessment last revised 1991).

### A2-7.3.3 Selection of Exposure Limits

The estimates of the carcinogenic potencies of inhaled copper and non-cancer effects of ingested copper, developed by the Institute of Medicine (IOM) and the California Air Resource Board (CARB) will be used to assess potential human health risks associated with exposure to copper at this site. The selected exposure limits and the health effects upon which they are based are summarized below (Table A2-13).

**Table A2-13: Selected Exposure Limits for Copper**

| Route of Exposure | Exposure Limit | Toxicological Basis | Source Agency |
|---|---|---|---|
| Non-Cancer Effects | | | |
| Ingestion | 140 µg/kg-day | liver damage | IOM, 2001 |
| Inhalation | 2.4 µg/m$^3$ | chronic reference exposure limit - respiratory | CARB, 1998 |
| Cancer Effects | | | |
| Ingestion | N/A[1] | - | - |
| Inhalation | N/A | - | - |

1. Not Applicable

### A2-7.4 Copper References

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## A2-8 Toxicological Profile for Lead

Lead is a bluish-white lustrous metal. It is very soft, highly malleable, ductile and a relatively poor conductor of electricity. It is very resistant to corrosion but tarnishes upon exposure to air. Lead pipes bearing the insignia of Roman emperors, used as drains from the baths, are still in service. Alloys include pewter and solder. Tetraethyl lead was used in some grades of petrol (gasoline).

### A2-8.1 Pharmacokinetics

The absorption, distribution, metabolism, and elimination of lead has been extensively studied in both animals and humans. Available data can be used to quantify the uptake and disposition of lead in the human body for various populations of children and adults. Lead absorption is influenced by the route of exposure, chemical speciation, the physicochemical characteristics of the lead and exposure medium, and the age and physiological states of the exposed individual (eg., fasting, nutritional calcium and iron status). There is a significant body of data available in the scientific literature evaluating lead absorption from soil (summarized in NEPI, 2000).

The primary sites for inorganic lead absorption are the gastrointestinal and respiratory tracts. The bioavailability of ingested soluble lead in adults may vary from less than 10% when ingested with a meal to 60 – 80% when ingested after a fast. Immediately following absorption, lead is widely distributed to blood plasma and soft tissues, then it redistributes and accumulates in bone (ATSDR, 1993).

Bone lead accounts for approximately 73% of the total body burden in children, increasing to 94% in adults due to changes in bone turnover rates with age. Transplacental transfer of lead has been demonstrated based on measurements of lead in umbilical cord blood in humans, as well as tissue concentrations in offspring of mice.

Lead that is not retained in the body is excreted principally by the kidney as salts or through biliary clearance into the gastrointestinal tract in the form of organometallic conjugates. Excretion rates measured in infants, children, and adults are highly variable, although available data suggest that the fraction of absorbed lead that is retained in humans decreases with age (ATSDR, 1993).

Dermal absorption of lead compounds is less significant than either oral or inhalation routes of exposure (ATSDR, 1993). Information on the dermal absorption of lead containing compounds is limited to a single study, which applied a lotion containing lead acetate to the forearms of male volunteers and reported a dermal absorption rate of approximately 0.06% over a 12 hour period (ATSDR, 1993).

The toxicokinetics of lead seem to be affected by the polymorphism of the enzyme delta-aminolevulinic acid dehydratase (ALAD) (Smith et al., 1995). ALAD is a polymorphic enzyme with two common alleles, ALAD*1 and ALAD*2 (Petrucci et al., 1982). Gerhardsson et al., (1999) investigated the mobilization of lead by use of the chelating agent 2-3-meso-dimercaptosuccinic acid in male lead smeltery workers. Two workers with the ALAD*2 allele seemed to mobilize less chelatable lead in relation to their blood, plasma, and urine concentrations of lead than the other workers. Smith et al., (1995) suggest that ALAD*2 in circulating red blood cells bind lead more avidly than ALAD*1, thus increasing the blood lead level, but at the same time decreasing the amount of lead delivered to soft tissues.

### A2-8.2 Toxicology

#### A2-8.2.1 Non-Cancer Effects

The potential for lead to impair neurobehavioural development in children is the subject of much concern. Acute inhalation and oral exposures to lead often results in central nervous system effects including; dullness, restlessness, irritability, poor attention span, headaches, muscle tremors, hallucination and loss of memory (Health Canada 1992). Encephalopathy has been reported at very high lead exposure levels (100 µg lead/deciliter of blood in adults and 80 µg/dL in children) (Health Canada 1992).

Chronic exposure to elevated levels of lead can result in a number of nervous system effects. Tiredness, sleeplessness, irritability, headaches, joint pain and gastrointestinal symptoms have all been reported (Health Canada, 1992). In adults, these effects are seen at blood lead levels of 50 - 80 µg/dL. Occupationally exposed persons have been found to suffer from muscle weakness, mood disruptions, and peripheral neuropathy when blood lead levels reached 40 - 60 µg/dL. At levels of 30 - 50 µg/dL, significant reductions in nerve conductive velocities were also reported (Health Canada, 1992). Renal disease has also been reported, but nephropathy has not been detected in adults or children whose blood lead levels were below 40 µg/dL (Health Canada, 1992).

There is substantial human evidence in both adults and children which demonstrates that both the central and peripheral nervous system are the primary targets of lead toxicity. Sub-encephalopathy, neurological and behavioral effects in adults and electrophysiological evidence of nervous system damage in children have been reported at blood lead levels as low as 30 µg/dL (Health Canada, 1992). A number of epidemiological studies have examined the effects of lead exposure in young children. The studies were able to demonstrate no clear threshold below which the detrimental effects of lead on child neurological development does not occur (Health Canada, 1992).

Epidemiological studies of occupationally exposed adults were not able to demonstrate an increase in cancers among an exposed cohort compared to control. The International Agency for Research on Cancer (IARC, 1987), considers the overall evidence of lead carcinogenicity in humans to be inadequate. Animal studies have reported renal tumors in rats exposed to 1,000 µg lead salts/g in the diet. While exposures to lead acetate, subacetate and phosphate salts produced renal tumors in rats, equivalent exposures to other lead salts did not result in the production of renal tumors (Health Canada, 1992). Health Canada has classified lead as a Group IIIB (possibly carcinogenic to humans) compound based on a lack of adequate human data and limited evidence of carcinogenicity in animals.

Epidemiological studies have indicated that non-cancer neurological effects may occur at very low exposure levels. Therefore, an exposure level based on these effects will provide against the possible carcinogenic effects of lead. Health Canada (1996) recommended a provisional tolerable daily intake (PTDI) for lead of 3.57 g/kg-day. This value was based on technical reports from annual meetings of the Joint FAO/WHO Expert Committee on Food Additives (JECFA) (WHO, 1993), and epidemiological studies associating lead exposure with neurological effects in infants and children. The WHO value was established to prevent increases in blood lead levels in children. Studies with young children have shown that daily exposures to lead in the 3 - 4 µg/kg-day range do not alter the blood lead level in the study children. Intakes at or above 5 µg/kg-day resulted in significant increases in blood lead levels.

### A2-8.2.2 Cancer Effects

The US EPA (US EPA IRIS, 1998 - carcinogenicity assessment last revised 1993) has classified lead as a probable human carcinogen based on sufficient animal evidence. However, the Carcinogen Assessment Group (US EPA IRIS, 1998) did not recommend derivation of a quantitative estimate of oral carcinogenic risk, due to a lack of understanding pertaining to the toxicological and pharmacokinetic characteristics of lead. In addition, the neurobehavioural effects of lead in children were considered to be the most relevant endpoint in determining an exposure limit.

Health Canada (1992) classified lead in Group IIIB (possibly carcinogenic to humans) by ingestion. Lead and inorganic lead compounds have been placed in Group 2B (possible human carcinogen) by ingestion under IARC (1987).

### A2-8.2.3 Susceptible Populations

There is a very large database which documents the effects of acute and chronic lead exposure in adults and children. Extensive summaries of the human health effects of lead are available from a number of sources including Health Canada, the US EPA IRIS database and the ATSDR. These reviews show that infants, young children up to the age of six and pregnant women (developing fetuses) are the most susceptible (Health Canada, 1992).

## A2-8.3 Current Exposure Limits

### A2-8.3.1 Oral and Inhalation Exposure Limits

Health Canada (1996) recommended a provisional tolerable daily intake (PTDI) for lead of 3.57 µg/kg-day. This value was based on technical reports from annual meetings of the Joint FAO/WHO Expert Committee on Food Additives (JECFA) (WHO, 1993 - as cited in Health Canada, 1996), and epidemiological studies associating lead exposure with neurological effects in infants and children.

Based on a critical blood lead level of 100 µg/L for cognitive deficit, hearing impairment and disturbed vitamin D metabolism in children, the annual average air lead level should not exceed 0.5 µg/m$^3$ (WHO, 2000).

The Ontario Ministry of Environment and Energy recommended an IOC$_{pop}$ (intake of concern for populations) of 1.85 µg/kg-day which incorporated the population-based significance of the health effects and attempted to minimize the predicted number of children with individual blood lead levels of concern (MOEE, 1994). Sub-clinical neurobehavioural and developmental effects were the critical effects appearing at the lowest levels of exposure (MOEE, 1994). The IOC$_{pop}$

was based on an LOAEL in infants and young children of 10 µg/dL, converted to an intake, with an applied uncertainty factor of two for the use of an LOAEL (MOEE, 1994).

### A2-8.3.3 Selection of Exposure Limits

See discussion in Section 5.8 (Main report - Part B).

### A2-8.4 Lead References

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## A2-9 Toxicological Profile for Nickel

Pure nickel is a hard, silvery-white metal, which has properties that make it very desirable for combining with other metals to form mixtures called alloys. Some of the metals that nickel can be alloyed with are iron, copper, chromium and zinc. These alloys are used in making metal coins and jewelry and in industry for making items such as valves and heat exchangers. Most nickel is used to make stainless steel. Compounds of nickel combined with many other elements, including chlorine, sulfur and oxygen exist. Many of these compounds dissolve fairly easily in water and have a characteristic green color. Nickel and its compounds have no characteristic odor or taste. Nickel compounds are used for nickel plating, to color ceramics, to make some batteries, and as substances known as catalysts that increase the rate of chemical reactions (ATSDR, 1997).

The physiological role of nickel in animals and humans has not yet been determined. It is believed, based on plants and microorganisms, that nickel is involved as a cofactor in metalloenzymes/proteins or as a cofactor which facilitates iron absorption in the intestine (Nielsen, 1985). Nickel may also affect endocrine function regulating prolactin levels. Nickel deficiency has not been observed in humans, but has been induced in animals, indicating that nickel is an essential element for animals (Schnegg and Kirchgessner, 1975).

An important issue relating to nickel toxicity is its speciation. Its form (metallic, salt, oxide etc.) and solubility strongly influence its toxicology. The solubility (in water) of different nickel compounds ranges from the highly soluble nickel salts (nickel chloride - 642 g/L; nickel sulphate - 293 g/L) down to the insoluble nickel oxide (1.1 mg/L) and the sparingly soluble nickel subsulphide (517 mg/L) (ATSDR, 1997). Some of the more insoluble nickel compounds (ie., nickel oxide, nickel subsulfide may have higher solubilities in biological fluids (Yamada et al., 1993; Ishimatsu et al., 1995; Oller et al., 1997). The predominant nickel species in Rodney Street soils is the relatively insoluble nickel oxide (Results section of Part A).

The toxicity of nickel can be classified into four separate categories: (1) non-cancer respiratory and other disorders, due to the inhalation or ingestion of nickel compounds; (2) cancer, due to inhalation of nickel compounds; (3) allergy, a hypersensitivity to nickel manifested by contact dermatitis and asthma; and (4) iatrogenic poisoning which may have occurred in the past in patients undergoing hemodialysis, corrosion of stainless steel prostheses, and nickel-contaminated medication or medication such as disulfiram that caused increased nickel concentration in the blood (not discussed).

### A2-9.1 Pharmacokinetics

### A2-9.1.1 Inhalation Exposure

Following inhalation exposure, nickel may deposit in the lungs depending on the size of the particle inhaled. Larger particles (5 - 30 µm) tend to accumulate in the upper respiratory tract while smaller particles are deposited in the lower respiratory system (see section A2-9.2.1.1). Absorption of nickel compounds deposited in the lung into the blood stream depends upon their form and solubility. Soluble nickel compounds such as nickel chloride and nickel sulphate are absorbed readily (up to 100%) from the respiratory tract, while almost none of the less soluble nickel compounds such as nickel oxide and nickel subsulphide (as demonstrated by urinary nickel levels in exposed workers) are absorbed. Inhaled nickel that is absorbed is excreted through the urine. Studies conducted on nickel workers show that nickel urinary excretion increased towards the end of the shift and also towards the end of the work week, indicating that one fraction is removed quickly, but that there was also a fraction which was removed more slowly (Ghezzi et al., 1989; Tola et al., 1979; as cited in TERA, 1999).

No reliable estimates are, however, found in the literature for retention and uptake of nickel from solely nickel oxide inhalation exposure in humans. Recently, Yu et al., (2001) have developed a dosimetry model for inhaled nickel compounds using occupational exposure data and information from studies of rats inhaling nickel.

Occupational exposure to nickel results in higher nickel lung burdens than the general population. Workers exposed to insoluble forms of nickel (such as nickel oxide and nickel sulphide) have higher nickel levels in the nasal mucosa than those workers exposed to more soluble forms of nickel (this may be related to larger inhalable dust particles being trapped in the upper respiratory tract). Less soluble nickel compounds, therefore, appear to remain in the nasal passage following inhalation exposure. Serum nickel levels are higher in workers exposed to soluble nickel compounds in comparison to those exposed to insoluble nickel compounds (Torjussen and Andersen, 1979, as cited in ATSDR, 1997). Nickel sensitized individuals had similar nickel levels in blood, urine and hair relative to non-sensitive individuals (Spruit and Bongaarts, 1977, as cited in ATSDR, 1997).

Pulmonary exposure to green nickel oxide in rats resulted in nickel excretion in the feces, but not in the urine, indicating that the primary removal mechanism of nickel oxide involved clearance from the lungs rather than by dissolution-absorption processes (Benson et al., 1994 as cited in ATSDR, 1997). The observed excretion could also reflect mucociliary clearance (being brought up in mucus and then being swallowed), in addition to macrophage clearance. Benson et al., (1994) also found that nickel subsulphide is cleared relatively rapidly (half life of four days) from the lungs of rats. They concluded that nickel subsulphide is relatively insoluble in water, but dissolves rapidly in lung fluid.

#### A2-9.1.2 Oral Exposure

Studies examining the absorption of nickel by humans found that nickel sulphate was up to 40 times more bioavailable if administered in water than in food (Sunderman et al., 1989). The bioavailability of nickel also increased when administered in a soft drink, but not when given in milk, coffee, tea or orange juice (Solomons et al., 1982). Serum nickel levels were found to be elevated in subjects who had fasted prior to the administration of nickel in drinking water, but this was not the case for those who were administered nickel in food. Food tends to decrease the bioavailability of nickel. Some nickel sensitive individuals were found to have decreasing nickel serum concentrations and increasing nickel urinary concentrations with increased administered nickel concentrations (Santucci et al., 1994). This may be an indication that some nickel sensitive individuals can decrease nickel absorption in response to increased nickel intake. In non-occupationally exposed people, nickel concentrations tend to be highest in lungs, thyroid and adrenal glands, kidney, heart and liver (Rezuke et al., 1987, as cited in ATSDR, 1997). The total amount of nickel estimated to be present in the human body is about six mg for a 70 kg adult (Sumino et al., 1975, as cited in ATSDR, 1997).

Quantitative absorption data for unspecified forms of soluble nickel are as follows: 1 - 27% of ingested nickel is absorbed (depending on whether food is consumed); approximately 1 - 6% of nickel administered with food or during a meal is absorbed; 12 - 27% of nickel absorbed after a fast (data from Diamond et al., 1998, as cited in *TERA*, 1999).

Bioavailability and bioaccessibility of nickel is further discussed in Appendix 5.

Nickel metabolism occurs via a series of nickel exchange reactions (Sarkar, 1984, as cited in ATSDR, 1997). In human blood, nickel binds to a blood protein called albumin. Nickel competes with copper for a binding site on the albumin (Hendel and Sunderman, 1972, as cited in ATSDR, 1997). Nickel is then transferred from the albumin to L-histidine, an amino acid. The nickel-histidine complex has a low molecular weight and can easily cross biological membranes (Sarkar, 1984, as cited in ATSDR, 1997). Nickel is also tightly bound to a nickeloplasmin in human blood which is not available for exchange and hence not transported across biological membranes (Sunderman, 1986, as cited in ATSDR, 1997).

Most ingested nickel is excreted via feces, although the nickel absorbed by the gastrointestinal tract is excreted in the urine. In comparison, studies of nickel doses administered with food or water, 26% of the dose given in water was eliminated in the urine and 76% in the feces by the fourth day following administration (Sunderman et al., 1989). In contrast, 2% of the nickel dose administered in food was eliminated in the urine and 102% was eliminated in the feces during the same time period. Nickel can also be eliminated through hair, sweat, milk and skin.

No reliable estimates are, however, found in the literature for retention and uptake of nickel from nickel oxide ingestion exposure.

### A2-9.1.3 Dermal Exposure

Studies of the dermal uptake of nickel in humans have been summarized in Appendix 7.

### A2-9.2 Toxicology

### A2-9.2.1 Inhalation Exposure

In two year inhalation studies of nickel oxide, nickel subsulfide, and nickel sulfate in rats and mice, respiratory lesions observed for all compounds included increased lung weights, focal alveolar/bronchiolar hyperplasia, inflammation and/or fibrosis of the lung, and lymphoid hyperplasia of the lung-associated lymph nodes (Dunnick et al., 1995; NTP 1996a, 1996b, 1996c). The investigators noted that qualitatively the inflammatory responses in the lungs were similar with all three compounds; however, the effects were more severe after exposure to nickel oxide and nickel subsulfide. In addition to lung effects, atrophy of the olfactory epithelium was also observed after exposure to nickel sulfate. Compared to rats, mice were more resistant to the development of lung lesions following nickel exposure.

The only data available for chronic nickel inhalation exposure for humans is limited to occupational data. One of the limitations associated with the epidemiological data available is that the workers were exposed to several different forms of nickel as well as other metals and irritant gases at the same time. As a result, the observed effects can not be attributed to a particular type of nickel. Other lifestyle factors, such as smoking, which affect disease outcomes, are also not always accounted for, thereby limiting the conclusions that can be drawn. Cancer effects related to inhalation exposure are further discussed in section A2-9.2.3.

One death has been reported as the result of exposure to very high metallic nickel concentrations (382 mg/m$^3$) of a small particle size (Sunderman, 1993, as cited in ATSDR, 1997). Workers who were chronically exposed to nickel oxide or metallic nickel at concentrations greater than 0.04 mg/m$^3$ had a greater incidence of death from respiratory disease (Cornell and Landis, 1984; Polednak, 1981, as cited in ATSDR, 1997). Other respiratory effects found included chronic bronchitis, emphysema, and reduced vital capacity. These workers were also exposed to other metals, so it can not be concluded that nickel is the sole causative agent of the effects observed. Asthma from primary irritation and as the result of dermal sensitization has also been documented amongst nickel workers (Dolovich et al., 1984; Novey et al., 1983; Shirakawa et al., 1990; as cited in ATSDR, 1997). Increased incidence of cardiovascular related deaths has not been found in nickel workers.

Nickel refinery workers with elevated urinary nickel concentrations also showed a significant increase in urinary $\beta_2$-microglobulin levels, which is indicative of tubular dysfunction in the kidneys (ATSDR, 1997). However, marked differences are seen between the results using single urine samples ("spot samples"), and sampling conducted over a 24 hour period *(TERA*, 1999). Although male and female workers were exposed to the same average nickel (nickel chloride and nickel sulphide) air concentrations, the women had twice the nickel urinary concentrations of the men (Sunderman and Horak, 1981, as cited in ATSDR, 1997). A study of nickel production workers has found significant increases in levels of immunoglobulin G (IgG), IgA, and IgM as well as a significant decrease in IgE. Serum proteins involved in cell-mediated immunity also increased, suggesting stimulation of the immune system by nickel (Bencko et al., 1983, 1986; as cited in ATSDR, 1997). The *TERA* (1999) report concluded that "the overall epidemiological database regarding potential kidney effects of inhalation exposure to soluble nickel is weak. However, the available data do provide suggestive evidence that the kidney can be affected under exposure conditions below those causing acute toxicity."

Studies show that pregnant female workers at a nickel refining plant in the Kola region in Russia had a 15.9% increase in spontaneous abortions in comparison with a control population of pregnant female construction workers (who were not occupationally exposed to nickel) who had a spontaneous abortion rate of 8.5% (Chashschin et al., 1994). The Russian metal refinery workers were exposed to nickel sulphate concentrations of approximately 0.08 to 0.196 mg nickel/m$^3$ and corresponding urinary nickel concentrations were 3.2 to 22.6 µg/L. Nickel urinary concentrations in persons not occupationally exposed range from <0.1 to 13.3 µg/L. Heavy lifting and heat stress are also associated with nickel refining. A preliminary study of pregnant Russian nickel refinery workers also indicated that babies born to these women had a 16.9% increase in development effects (primarily cardiovascular and musculoskeletal defects), relative to the children of construction workers who had a 5.8% increase in developmental effects. It is not clear whether the fact that the Russian workers also were exposed to heavy lifting and heat stress contributed to the observed abortions. No indications of fetal toxicity (birth weight of first child) in the general population in nickel smelter cities in the Kola region in Russia (Nikel and Zapoljarnij) were found in a large comparative study of pollution and health in the Norwegian-Russian border area. Further studies are in progress (Smith-Sivertsen et al., 1997; Odland, 1999).

A significant increase of gaps in the chromosomes was found in white blood cells of nickel workers who were exposed to nickel monosulphide and nickel subsulphide. Breakage or exchange of the chromosomes was not observed. The study did not find any correlation between the incidence of the chromosome gaps, blood nickel concentration, duration of nickel exposure, or age of workers (Waksvik and Boysen, 1982, as cited in ATSDR, 1997).

It should be noted that the effects discussed in these paragraphs require absorption from the lungs and systemic distribution of nickel, which would be unlikely to occur following inhalation exposure to nickel oxide alone.

#### A2-9.2.1.1 An Examination of Nickel on Airborne Particulates in Occupational and Environmental Settings

In order to characterize the potential risk of lung cancer due to airborne nickel in ambient air, a number of the exposure parameters and assumptions relating to the development of the unit risk factor and the characteristics of the nickel in the ambient air being inhaled need to be examined. Airborne nickel compounds are typically associated with suspended particles. The potential risk of inhaling particles is determined by several parameters including:

particle size characteristics;

chemical composition or speciation; and

mass concentration.

In addition, the type of breathing patterns and duration of exposure of the receptor will influence the intake or dose of nickel to the lungs (Casarett and Doull, 1991; Snipes et al., 1997; Health Canada, 1999; Yu et al., 2001).

The unit risk factors available from US EPA (1986), WHO (2000) and Health Canada (1996) to characterize lung cancer risk are all based on extrapolations from lung cancer incidence in nickel refinery workers and various assumptions and estimates of airborne nickel in the workplace of these workers. Actual measurements of the airborne nickel in these workplaces during the period when the workers received the exposure resulting in lung cancer are limited because this period predates the use of appropriate technology to monitor workplace hygiene and exposures.

#### Particle Size Characteristics and Air Sampler Design

Information about particle size characteristics is important for understanding how suspended particles behave in the human respiratory tract and predicting lung exposures. Information on the design of air sampling devices used in the workplace and the environment can be used to evaluate and compare inhalation estimates from different sources and evaluate the relevance of estimates based on previous definitions of inhalable and respirable fractions and historical methods of air sampling. For example, much workplace air sampling is based on personal air samplers which are worn on the worker close to the breathing zone. Stationary monitoring of particles in a particular work area is not considered representative of the inhalation exposure of a worker moving about the workplace and is only measured sporadically if at all. By contrast, environmental monitoring mainly involves air sampling at fixed sites, usually related to known emission sources. The use of personal air samplers to monitor environmental air levels as people move around during the day has been implemented for short periods on small populations in Ontario at specific locations (Hamilton (HAQI, 1997), Windsor (MOEE, 1994)).

The behaviour of suspended particles in the human respiratory tract is well studied in both occupational and environmental situations (Casarett and Doull, 1991; Snipes et al., 1997; Health Canada 1999; Yu et al., 2001). The size and aerodynamic properties of suspended particles influences how far a particle penetrates the respiratory tract, where it deposits, and its retention behaviour. The human respiratory tract can be divided into the nasopharyngeal region (nose, mouth and throat portion), the tracheobronchial region where the windpipe, and the major conducting airways of the lung connect with the pulmonary region of the lung where gas exchange takes place (here air passages are tiny and end in little air sacs or alveoli). Only part of the total quantity of suspended particles present in the breathing zone of the receptor is inhaled. Particles with an aerodynamic diameter of 5 to 30 µm are largely deposited in the nose, mouth and throat, the majority of particles with aerodynamic diameters of 1 to 5 µm are inhaled past this region and are deposited in the tracheobronchial region and particles < 0.5 µm are inhaled (or repired) right into the alveoli in the deepest parts of the lung (Casarett and Doull, 1991). The patterns of deposition of different sized particles reflect the combination of particle size, narrowing air passages, reduced air velocity and changes in airflow direction as particles penetrate the different regions of the respiratory tract (Snipes et al., 1997; Yu et al., 2001). An important factor that can influence this pattern of deposition is the pattern of breathing. During quiet breathing, most breathing occurs through the nose (nasal breathing) and the inflation of the lung is small. Consequently, the nasal passages scavenge larger particles and a large portion of the inhaled particles are exhaled. During exercise, larger and larger volumes of air are inhaled and at some stage, the person switches over to mainly mouth breathing and particles can penetrate deeper into the lower regions of the lungs.

Suspended particles can be classified into various fractions depending on particle size and degree of penetration into the respiratory tract. In the workplace, air sampling is mainly indoors and personal, ie., the air sampler is attached to the worker. For particle monitoring in the workplace, there is a recently accepted international definition of health-related sampling criteria based on progressively finer sized particle fractions: inhalable, thoracic or respirable (ACGIH (1998 ). The inhalable fraction represents particles that enter the mouth and nose (the particle size (aerodynamic diameter) has a 50% cut-point or particle size corresponding to 50% sampling efficiency of 100 µm). The thoracic fraction represents inhalable particles that pass into the trachea and the larger upper airways of the lung (the 50% cut-point is 10 µm). The respirable fraction is the portion of inhalable particles that enter the deepest part of the lung (the 50% cut-point is 4 µm). These new definitions of sampling criteria are being used to implement new designs for air monitoring sampling devices for the workplace, and, to derive new workplace exposure criteria based on these new sampling criteria. For example, ACGIH adopted new TLVs for nickel compounds in 1998 based on conversion factors for the relative efficiencies of specific air samplers. This resulted in the old TLV for metallic nickel, insoluble nickel and nickel subsulphide changing from 1 mg/m$^3$ to 1.5 mg/m$^3$ for metallic nickel, 0.2 mg/m$^3$ for insoluble nickel and 0.1 mg/m$^3$ for nickel subsulphide, respectively. The TLVs for soluble nickel and nickel carbonyl were unchanged.

The older "inspirable" or "total" fraction had a 50% cut-point of less than 100 µm and the "respirable" fraction had a 50% cut-point range of 3.5 to 5 µm. Recent studies show that the new "inhalable" personal monitors tend to collect about twice the particle mass collected by the old "total" or "inspirable" personal air samplers (Werner et al., 1999).

By contrast, outdoor ambient air monitoring uses larger air pumping devices (hi-vol and lo-vol) and larger area filters than personal samplers and are subject to different conditions than indoors, eg., wind. Total suspended particulate (TSP) filters have a poorly defined cut-point ranging from 50 µm down to 22 µm depending on wind speed and may retain from submicron up to 50 µm particles. $PM_{10}$ filters have a 10 µm cutpoint and may cover the submicron to 10 µm particles and addresses the thoracic fraction particles. $PM_{2.5}$ filters have a 2.5 µm cut-point and cover the submicron to 2.5 µm particles and are meant to address the issue of fine, submicron particles which penetrate down to the alveoli (Health Canada, 1999).

Outdoor air monitoring is complicated by the occurrence of bi-modal and tri-modal particle size distributions in environmental aerosols. Environmental aerosols tend to be bimodal with a fine, submicron mode distributed between 0.1 µm and 1 µm and a coarse mode distributed from 1 µm out to 100 µm with a maximum in the 10 µm to 30 µm range. The fine mode represents fine, carbonaceous particles from combustion sources and the coarse mode represents crustal particles eroded from surface material. A third intermodal distribution with a maximum between 1 µm and 5 µm occurs but it is not clear whether this is artefactual or real (Snipes et al., 1997, Health Canada, 1999).

To summarize, in terms of how to interpret occupational and environmental air sampling data, the new IOM "inhalable" personal sampler collects about twice the particle mass collected in the old "total" personal sampler. This difference mainly relates to improved collection of coarser particle sizes that may deposit in the nose, mouth or throat. The TSP sampler shares some characteristics (particle size and mass range) with the old "total" personal sampler. The $PM_{10}$ sampler collects about half the mass collected in the TSP sampler and addresses the particle size range inhaled into the thoracic and respirable regions of the respiratory tract. The occupational "respirable" sampler would be expected to sample a slightly larger range of respirable particles than the $PM_{2.5}$ sampler. The particle mass collected by "respirable" and $PM_{2.5}$ samplers would normally be expected to be less than the larger particle size range samplers unless the "respirable" particle fraction is increased by some process.

**Particle Size Characteristics of Nickel Refinery Dust**

Information on the particle size distribution and nickel speciation of the aerosols in the nickel refineries associated with increased lung cancer mortality used to derive inhalation unit risks is relatively unknown. A study of side-by-side sampling of workers wearing both the "total" aerosol sampler (37 mm closed face cassette) and an inhalable aerosol sampler (the IOM personal aerosol sampler) showed that the level of exposure based on inhalable aerosol consistently exceeds the that for "total" aerosol. The observed bias ranged up to three fold especially in workplaces with coarse aerosols (Werner et al., 1999).

Several studies have also evaluated the contribution of the "respirable" fraction to the inhalable or total fraction in nickel refineries and suggest that the respirable fraction is < 10% (Thomassen et al., 1999; Werner et al., 1999). The overall implication is that workplace atmospheres contain a larger proportion of larger, coarse particles that may not penetrate beyond the nose, mouth or throat.

### Particle Size Characteristics of Airborne Particulate in Port Colborne

By comparison, the results of many years of sampling ambient outdoor air particles in Ontario typically show mass ratios of 100:40: 24 for TSP, $PM_{10}$ and $PM_{2.5}$, respectively (information from Neil Buonocore, Supervisor, Air, Pesticides & Environmental Planning, West Central Region, MOE). Extensive federal air monitoring across Canada yields similar ratios of 100:50:25 for TSP, $PM_{10}$ and $PM_{2.5}$, respectively (Health Canada, 1999).

An added complication is that MOE data on airborne nickel is based on hi-vol TSP samplers whereas the Environment Canada air samplers use lo-vol $PM_{10}$ samplers. In terms of lung cancer, the $PM_{10}$ data is more appropriate than TSP data, as it better represents the respirable fraction that would enter the lungs. However, the workplace air monitoring data is the old "total" inhalable fraction and its respirable fraction may be <10% of the "total" inhalable fraction. Essentially, the lung cancer risk estimate of ambient air in Port Colborne with an assumed nickel speciation based on soils containing elevated levels of nickel and measured using hi-vol TSP samplers is being characterized using a unit risk for lung cancer based on estimates of airborne nickel levels of particular nickel speciation in very dusty workplaces using personal air sampling devices.

### Chemical Composition / Speciation in Nickel Refinery Dust

Nickel refinery dusts of the era when nickel workers were exposed to airborne nickel levels associated with respiratory cancer contained varying percentages of metallic, oxidic, sulfidic and soluble nickel (see Table 3, Doll et al., 1990 - details of the specific plants, areas of the plant and nickel refining process involved can be obtained from the references in Doll et al., 1990).

A dust sample from the Port Colborne refinery taken in 1959 (Gilman and Yamashiro, 1985) is described as containing 58% nickel subsulphide ($Ni_3S_2$), 20% nickel sulphate ($NiSO_4 6H_2O$) and 6.3% nickel oxide (NiO). This dust was used in animal carcinogenicity testing (Gilman and Ruckerbauer, 1962). This represents an elemental nickel content of about 51% by weight. US EPA (1986) has based nickel speciation assumptions on the composition of these nickel refinery flue dusts.

Dust samples taken from the Clydach, UK refinery and believed to represent dusts from 1920 and 1929 contained 37.5% and 26.7% nickel by weight, respectively. X-ray powder diffraction analysis indicated that nickel oxide peaks were prominent in spectra from both samples (Draper et al., 1994).

Dusts from the Port Colborne refinery were analyzed by Inco in 1978. Three dusts from nickel refining processes contained nickel levels ranging from 38.6% (Cottrell precipitator), 42.9% (Tumblast stack dust), to 72.2% nickel (Submerged Combustion Evaporator stack emission (SCE)) by weight. X-ray diffraction microprobe analysis of the Tumblast stack dust showed that there were two major phases, a nickel-magnesium-silicon alloy (50% Ni, 20% Mg, 30% Si), and a nickel-magnesium alloy (80% Ni, 20% Mg). Other phases also contained iron. In the Cottrell precipitator dust, the most prevalent compound was nickel oxide, followed by lead sulphate; nickel sulphate and copper sulphate were minor phases. In the SCE stack emission sample, the only compound detected was nickel oxide. It is not known whether any of these processes vented directly to the outside or were a component of stack emissions.

Andersen et al., (1996) assumed that the nickel species occurred in respirable dust at the Kristiansand, Norway refinery in the same proportion as the material being handled in various work areas. Nickel species were divided into four categories: metallic nickel, oxidic nickel and sulphidic nickel (all grouped as insoluble), and, soluble nickel (nickel sulphate, nickel chloride, nickel carbonate and nickel hydroxide). Nickel oxide is cited as the most frequent form of nickel in the roasting and calcining areas of the refinery (Andersen et al., (1996)), however, Grimsrud et al., (2000) indicate that relatively higher proportions of soluble nickel (4% to 40%) may have been present. The percentage of nickel subsulphide would be correspondingly lower (T. Norseth - personal communication).

Stationary monitoring at the Finnish nickel refinery where the process involves leaching of matte and electrowinning of nickel from solution, indicates most of the airborne nickel is in the form of dry crystalline salts (95% nickel sulphate), except at the leaching site where 11% was insoluble forms of nickel (Kiilunen et al., 1997).

Nickel speciation results at a Russian refinery using older refining processes showed that the predominant chemical form in electrorefining department workroom air was soluble nickel (55 - 99%); oxidic and sulfidic nickel constituted, respectively, <0.6 - 34% and 1 - 19% for various jobs, with very little in the metallic form. The amount of sulfidic was reduced substantially during matte roasting with a concomitant increase in the oxidic and metallic fractions. It was also noticeable that in the early stages of the roasting process, the amount of soluble nickel increased and that the workroom air concentration of soluble nickel was higher at the top of the roaster than in the electrolytic department (Thomassen et al., 1999).

In terms of speciation, it is clear that the assumed speciation of nickel on air particles in Port Colborne ambient air is different from the speciation of nickel in nickel refinery dust. North American nickel refinery dust appears to differ from the Norwegian nickel refinery dust in that nickel subsulphide may form up to 50% of the nickel species and nickel oxide is < 10%, whereas the percent of nickel subsulphide in the Norwegian nickel refinery dust is lower and the percent of nickel oxide is higher. The percent of soluble nickel in both nickel refinery dusts appears to be comparable.

### Chemical Composition / Speciation in Airborne Particulate in Port Colborne

No chemical speciation data are available for airborne nickel in Port Colborne, however, nickel speciation information available for selected Port Colborne soils is described in Part A, Results - Nickel Speciation (section 8.2).

In summary, all of the five laboratories which performed analysis of Rodney Street soils detected nickel oxide. Elemental or metallic nickel was detected by two laboratories. One laboratory measured nickel sulphide and traces of soluble nickel sulphate. These results indicate that a range of analytical techniques are required to characterize nickel species in soil. The overall results indicate that nickel oxide is the predominant form and ranges from 80% - 94% of the total nickel. Metallic nickel and nickel alloys with copper and cobalt were also observed. Low amounts of sulphidic nickel and soluble nickel would be expected given the "ageing" effects of soil breakdown processes and leaching by rainfall. On average, about 16% - 19% of nickel in Rodney Street community soils is acid-soluble (Appendix 5). It was assumed that airborne nickel in Port Colborne had similar speciation to the Rodney Street community soils.

### Mass Concentration in Nickel Refinery Dust

Estimates of mass concentration of total airborne nickel in nickel refineries are limited and generally come from monitoring periods (1970s and later) subsequent to the highest occupational exposures. The exposure estimates developed by Doll et al., (1990) have been widely used (Health Canada, 1996; Andersen et al., 1996). For the most part, workplace exposures were classified as "high", "low", etc. on the basis of job category and duration of employment. Occupational exposure to nickel has also been reviewed by Nieboer (1992). The critical workplace concentrations associated with excess respiratory cancer risk are 10 $mg/m^3$ for insoluble forms of nickel, and 1 $mg/m^3$ for soluble forms of nickel (Doll et al., 1990). The recent studies of workers exposed to a high percent of soluble nickel in workplace air suggest that the critical workplace concentration for soluble salts may be 0.5 $mg/m^3$ (Kiilunen et al., 1997, Anttila et al., 1998). It is controversial, however, whether the effects of this concentration are due to soluble nickel alone, or interactions with insoluble forms and/or smoking.

A description of environmental conditions in the Port Colborne sinter plant is found in the Appendix to Doll et al., (1990). Of interest is a description of dust testing at this facility in 1953 by the Ontario Department of Health, Division of Occupational Hygiene. Dust concentrations in the five samples ranged from 61 to 1075 $mg/m^3$. If the highest value is dropped, the average dust concentration was 156 ± 55 $mg/m^3$. If it is assumed that the percentage of elemental nickel in these dusts ranged from 27% to 51%, the airborne nickel concentration would have ranged from 42 to 80 $mg/m^3$. This estimate agrees with reported airborne nickel levels in a similar Ontario nickel refinery (Copper Cliff) over this time period (Doll et al., 1990). It is not known whether any of these processes vented directly to the outside or were a component of stack emissions.

The recent WHO air quality guideline for nickel used the exposure data of Doll et al., (1990) and updated epidemiology data from the Kristiansand, Norway cohort (Andersen et al., 1996; WHO, 2000). The exposure assessment is further discussed in Grimsrud et al., (2000) and involved several thousand personal measurements of total nickel in the breathing zone from 1973 to 1994, a period which overlaps the time span of the Andersen et al., (1996) cohort. Most of the personal sampling measurements were performed using a 37 mm filter cassette. Total nickel in this context may correspond with total nickel on TSP filters outdoors, however, the occupational measurements may address a nickel enriched atmosphere with a different particle size distribution than outdoors.

Workplace levels of airborne nickel comparable in magnitude to those reported or estimated for similar operations during the nineteen sixties and seventies in western Europe and North America have been measured in a Russian nickel refinery (Thomassen et al., 1999; Höflich et al., 2000).

**Mass Concentration in Airborne Particulate in Port Colborne**

MOE monitored airborne particulate (total suspended particulate (TSP)) and airborne nickel in Port Colborne at three locations from 1973 to 1996. The locations of the monitors (Hi-vol samplers) and the periods they were operated are:

Station 27030 located at Killaly Street East and James Street (about 1400 m NE of the refinery) from 1973 to 1985 (Avg = 0.278 $\mu g/m^3$). At this station, the annual average air concentration of nickel recorded in 1985, the year after the refinery ceased operation, was 0.088 $\mu g/m^3$. Station 27031 located at Killaly St East and Welland Avenue (about 1200m NW of the refinery) from 1973 to 1979. (The annual average air concentration of nickel for 1979 was 0.169 $\mu g/m^3$). Station 27047 located at Davis Street and Fraser Street (about 600m N of the refinery) from 1973 to 1996. The annual average air concentration of nickel for 1995, the last year with a full record was 0.023 $\mu g/m^3$. This airborne nickel concentration represented only 0.036% of the airborne particulate.

A new air monitoring station with TSP and $PM_{10}$ samplers located on Rodney Street and just west of and adjacent to the Inco facility began operation in July 2001. The results of sampling into early October are summarized in Tables A1-2A, A1-2B and A1-3, Appendix 1. These short term results show averages of 0.013 and 0.0059 $\mu g\ Ni/m^3$ for the TSP and $PM_{10}$ samplers, respectively. The corresponding air particulate data averages are 51.8 and 22.8 $\mu g/m^3$. This represents airborne nickel concentrations that are 0.025% to 0.026% of the airborne particulate. These TSP-based nickel levels are lower than those measured in 1995.

Air monitoring data from other sites in Ontario are also summarized in Appendix 1. Since Environment Canada's air monitoring network only reports data from lo-vol $PM_{10}$ and $PM_{2.5}$ samplers, the federal air data cannot be compared with Ontario's TSP data directly. Table A1-2b compares Environment Canada's data for sites in Southwestern Ontario with MOE $PM_{10}$ data from the Port Colborne in the Summer of 2001.

It would appear that the best comparison is of TSP-based airborne nickel levels to the old "total" personal air sampling data from the nickel refinery workers for estimating potential lung cancer risk associated with breathing Port Colborne air. The use of $PM_{10}$ and $PM_{2.5}$ data introduces a requirement to prorate older workplace exposure data so that "respirable" fractions are compared.

### A2-9.2.2 Oral Exposure

One death has been reported due to the accidental consumption of an extremely high nickel sulphate concentration (570 mg nickel/kg) by a two year old (Daldrup et al., 1983, as cited in ATSDR, 1997). Gastrointestinal effects were reported in an incident where workers drank water from a fountain containing nickel sulphate and nickel chloride (Sunderman et al., 1988). Exposure doses ranged from 7.1 to 35.7 mg nickel/kg. Symptoms included nausea, abdominal pain, vomiting and diarrhea. Neurological effects were also observed in the affected workers.

Oral lethality tests of rats indicated that soluble nickel compounds were more toxic than insoluble nickel compounds. An oral lethal dose for 50% of the population ($LD_{50}$) for nickel sulphate in female rats was reported to be 39 mg/kg while oral $LD_{50}$ values for insoluble nickel compounds were >3,930 and >3,665 mg/kg for nickel oxide and nickel subsulfide, respectively (Mastromatteo, 1986).

Decreased body weight has been observed in rats and mice given nickel chloride and nickel sulphate in drinking water (Schroeder et al., 1974). Ambrose et al., (1976) reported data on albino (Wistar) rats and beagle dogs exposed for two years to nickel sulphate in the diet at 100, 1,000 and 2,500 ppm. Non-cancer effects included decreased growth in dogs (mid and high doses) and rats (high dose), alterations in blood and urinary chemistry in high dose dogs, and changes in relative organ weights for mid and high dose female rats (heart and liver) and high dose dogs (kidney and liver). The No-Observable-Adverse Effects Level (NOAEL) was estimated to be 5 mg Ni/kg-day, based on the non-cancer changes in the rat. This study has been used as a supporting study for exposure limit development by US EPA IRIS (1998 - oral R*f*D assessment last revised 1996), WHO (1996), Health Canada (1996), and IOM (2001).

Increased albuminuria was observed in Wistar rats administered nickel sulphate in drinking water for six months (Vyskocil et al., 1994). Groups of male and female Wistar rats (n = 10) were given nickel (as sulphate) in the drinking water, at a concentration of 100 mg/L, for up to six months (Vyskocil et al., 1994). At six months, females exhibited a four fold increase in urinary excretion of albumin ($p<0.05$), as compared to age matched controls. Kidney weights in males were significantly increased. Absolute nickel intakes were estimated to range from 6.3 mg/kg/d to 8.4 mg/kg/d. Body weight gains and drinking water volumes consumed were comparable with those of age-matched controls. These results were attributed to nickel induced changes in glomerular permeability, particularly in females. In males, some treatment-related exacerbation of the normal age-related nephropathy could not be ruled out.

On behalf of the US EPA Office of Water, Metal Finishers of Southern California and Health Canada, Toxicology Excellence for Risk Assessment (*TERA*, 1999) conducted a review of a number of key studies of oral exposure involving soluble nickel. As part of this review, *TERA* (1999) identified a LOAEL of 7.6 mg/kg/day for the Vyskocil et al., (1994) study.

ATSDR (1997), and US EPA IRIS (1998 - oral R*f*D assessment last revised 1996) discuss the 90 day study with nickel chloride in water (0, 5, 35 and 100 mg/kg/day) administered by gavage to both male and female CD rats conducted by the American Biogenics Corporation (ABC, 1988). The body weight and food consumption values were consistently lower than those of controls for the 35 and 100 mg/kg/day dosed males. The 5 mg/kg/day group did not show any significant clinical signs of toxicity. There was 100% mortality in the high-dose group; 6/30 males and 8/30 females died in the mid-dose group (35 mg/kg/day). Histopathologic evaluation indicated that deaths of 3/6 males and 5/8 females in the mid-dose group were due to gavage errors. At sacrifice, kidney, liver and spleen weights for 35 mg/kg/day treated males and right kidney weights for 35 mg/kg/day treated females were significantly lower than controls. Based on the results obtained in this study, US EPA (IRIS) considered the 5 mg/kg/day nickel dose was a NOAEL, whereas 35 mg/kg/day was a LOAEL for decreased body and organ weights. This study was considered a supporting study by US EPA IRIS (1998 - oral R*f*D assessment last revised 1996) for development of their R*f*D.

A three generation study, carried out by Ambrose et al., (1976), noted a higher incidence of stillborns in the first generation of albino (Wistar) rats fed 250, 500 or 1,000 ppm nickel in their diet (nickel sulphate) and depressed body weights of weanlings on the 1,000 ppm diet in all generations. A higher incidence of stillborns was not observed in subsequent generations (Ambrose et al., 1976). Both parental and $F_1$ generations were treated for 11 weeks before mating. The study had some limitations including small sample size and use of pups rather than litters as the unit for comparison. No statistical analysis of the results was presented and a NOAEL or LOAEL has not been defined for this study.

ATSDR (1997), US EPA IRIS (1998 - oral RfD assessment last revised 1996), Velazquez and Poirier (1994) and WHO (1998) discuss a multi generation study using male and female CD rats exposed to nickel chloride in the drinking water at nickel concentrations of 50, 250, or 500 ppm (equivalent to 7.3, 30.8, or 51.6 mg nickel/kg/day) conducted by Research Triangle Institute (RTI, 1988). Animals were exposed to nickel in drinking water for 90 days before breeding. The highest exposure produced maternal toxicity characterized by a decrease in body weight and decreased absolute and relative liver weights of the dams. A decrease in the number of live pups per litter, an increase in pup mortality, and a decrease in the average body weight of the pups was noted for the $F1_a$ and $F1_b$ generations of the 500 ppm test group. Both the 50 and 250 ppm exposures have been considered to be a NOAEL (ATSDR, 1997, WHO, 1998, Velazquez and Poirier, 1984). However, US EPA IRIS (1998 - oral RfD assessment last revised 1996) did not consider RTI (1988) to be a supporting study in developing their RfD. Decreased food and water intake were observed in the exposed animals. For example, the low dose animals ranged from 1.75 mg Ni/kg/day to 11.78 mg Ni/kg/day as calculated on a weekly basis. Also, the room temperature was up to 6 °C higher than normal at certain times during gestation and the early postnatal days. Increased room temperatures have been reported to affect reproductive performance (National Research Council, 1996, Wolfensohn and Lloyd, 1998).

Smith et al., (1993) also studied the reproductive and fetotoxic effects of nickel. Four groups of 34 female Long-Evans rats were given drinking water containing nickel chloride in the following concentrations of nickel: 0, 10, 50 or 250 ppm (0, 1.3, 6.8 or 31.6 mg/kg/day) for 11 weeks prior to mating and during two successive gestation periods (G1, G2) and lactation periods (L1, L2). Maternal body weight gain was reduced during G1 in mid and high-dose females. The reproductive performance of the exposed rats was not affected. Pup birth weight was unaltered by treatment, and weight gain was reduced only in male pups exposed to 50 ppm nickel during L1. The most significant toxicological finding was the increased incidence of perinatal mortality. The proportion of dead pups per litter was elevated at the high dose in L1 and at 10 and 250 ppm in L2. The authors (Smith et al., 1993) consider the lowest dose (1.3 mg/kg/day) to be a LOAEL. While the perinatal mortality reported in this study is consistent with other reproductive studies on nickel, US EPA IRIS (1998 - oral RfD assessment last revised 1996) considered it hard to define a NOAEL and LOAEL because of the absence of a clear dose-response trend at the lower doses. Other agencies (Health Canada, 1996, WHO, 1998) consider 1.3 mg/kg/day to be a LOAEL.

Since the *TERA* (1999) review, an unpublished two generation reproduction study of orally administered nickel sulfate hexahydrate using Sprague Dawley rats was conducted at Springborn Laboratories in 2000 for the Nickel Producers Environmental Research Association (NiPERA) (Springborn, 2000). The test protocols were compliant with the OECD 416 test guidelines which are harmonized with current US EPA reproductive test guidelines (US EPA Office of Prevention, Pesticides and Toxic Substances (OPPTS) Series 870 Human Health Harmonized Test

Guidelines online at http://www.epa.gov/docs/OPPTS_Harmonized/870_Health_Effects_Test_Guidelines/ ). The range finding and definitive studies for this study were conducted using gavage (ie., oral intubation) as the route of exposure, due to palatability problems with nickel in drinking water and bioavailability problems with nickel in food. Some of the problems with delivering a precise dose to the animals is reduced, though a bolus effect may be involved. The range finding study was designed in two parts. The first part of the range finding studies was a dose-response probe utilizing small numbers of animals and nickel sulfate hexahydrate exposures of 0, 5, 15, 25, 50, 75, and 150 mg/kg/day. Lethality was observed at the 150 mg/kg/day exposure level.

The second part of the range finding study (ie., a one generation reproductive toxicity study) utilized nickel sulfate hexahydrate exposures of 0, 10, 20, 30, 50, and 75 mg/kg/day. These doses had no effect on parental survival, growth, mating behavior, copulation, fertility, implantation, or gestation length. However, evaluation of post-implantation/perinatal lethality among the offspring of the treated parental rats (ie., number of pups conceived minus the number of live pups at birth) showed statistically significant increases at the 30 to 75 mg/kg/day exposures and questionable increases at the 10 and 20 mg/kg/day levels.

Based upon the results of the one generation study, nickel sulfate hexahydrate exposure levels of 1, 2.5, 5.0, and 10 mg/kg/day (equivalent to 0.22, 0.56, 1.12 and 2.23 mg Ni/kg/day) were administered by gavage to five groups of male and female rats in the definitive two generation study. Males of the parental ($F_0$) generation were dosed during growth and for at least one complete spermatogenic cycle in order to elicit any possible adverse effects on spermatogenesis by the test substance. Females of the $F_0$ generation were dosed during growth and for several complete estrous cycles in order to elicit any possible adverse effects on estrous by the test substance. The test substance was administered to $F_0$ animals during mating, pregnancy, and through the weaning of their first generation ($F_1$) offspring. At weaning, the administration of the substance was continued to $F_1$ offspring during their growth into adulthood, mating and production of an $F_2$ generation, and up until the $F_2$ generation was weaned.

The results from the two generation study indicate that the highest dose selected (10 mg/kg/day or 2.2 mg Ni/kg/day) was a NOEL for adult and offspring rats for all the endpoints studied, including the variable of post-implantation/perinatal lethality. This study is under review by USEPA.

The selection of studies of oral exposures to soluble nickel salts for exposure limits is further discussed in section A2-9.3.2.

### A2-9.2.3 Cancer Effects

Extensive reviews of the toxicology of nickel and nickel compounds, including animal carcinogenicity and human epidemiological data, have been published (US EPA, 1986, IARC, 1990, Doll et al., 1990, CEPA, 1994, Hughes et al., 1994, *TERA*, 1999). The studies reviewed included human exposures associated with nickel mining, smelting, refining and high nickel alloy manufacture. The reviews also indicated that different classes of nickel compounds have different carcinogenic potencies.

### A2-9.2.3.1 Cancer Potential (Oral)

Increased tumourigenesis in mice, rats and dogs has not been associated with nickel compounds ingested in the diet or in drinking water (Schroeder et al., 1964; Schroeder and Mitchener, 1975; Ambrose et al., 1976).

Intrarenal injection of nickel subsulphide was reported to result in an increased incidence of renal tumours in male Fischer 344/NC rats (Higinbotham et al., 1992). Intrarenal administration of nickel subsulphide to male Fischer 344 rats was associated with an increase in kidney tumours (Sunderman et al., 1990). Nickel acetate was reported to induce a significant increase in lung tumours in rats following a series of intraperitoneal injections (Stoner et al., 1976).

### A2-9.2.3.2 Cancer Potential (Inhalation)

Numerous carcinogenicity experiments have been conducted with nickel compounds, administered via injection, inhalation or ingestion (reviewed by ATSDR, 1997 and *TERA*, 1999). Recent chronic inhalation studies have clearly indicated that different nickel compounds have different carcinogenic potentials and different animal species show different carcinogenic responses to various nickel compounds (NTP, 1996a,b,c).

Inhalation studies of the effects of nickel oxide concentrations of up to 42mg/m$^3$ on hamsters for a life-time did not show nickel induced carcinogenicity (Wehner et al., 1975 as cited in CEPA, 1994). However, rats exposed to 5 or 15 mg or nickel oxide via intratracheal instillation, demonstrated an increase in lung tumours (Pott et al., 1987, as cited in CEPA, 1994). Nickel oxide compounds also caused an increased incidence of tumours at the site of injection in various experimental animals (IARC, 1990).

A number of inhalation studies of nickel carcinogenesis in rats and mice have yielded positive results. Ottolenghi et al., (1974) exposed Fischer 344 rats to 0.97 mg nickel sulphide/m$^3$ for 78 weeks. An increased incidence of lung tumours was observed during treatment and during a 30 week observation period. Sunderman et al., (1957, 1959) also observed increased incidences of lung tumours in rats exposed to nickel carbonyl for up to 52 weeks.

The most recent chronic inhalation studies included up to two year inhalation exposures to nickel subsulphide, nickel sulphate hexahydrate and nickel oxide (NTP, 1996a,b,c).

In the nickel subsulphide inhalation study, rats were treated with 0, 0.11 or 0.73 mg Ni/m$^3$ and mice with 0, 0.44 or 0.88 mg Ni/m$^3$, 6 hours/day, 5 days/week for 104 weeks. NTP concluded that there was an increased incidence of alveolar/bronchiolar adenoma or carcinoma or squamous cell carcinoma in male and female rats, benign or malignant pheochromocytoma in males and benign pheochromocytoma in female rats. NTP concluded that there was no evidence of carcinogenic activity in mice and clear evidence of carcinogenic activity in male and female rats (NTP, 1996b).

In the nickel sulphate hexahydrate study, rats were exposed to 0, 0.03, 0.06 or 0.11 mg Ni/m$^3$, and mice were exposed to 0, 0.06, 0.11 or 0.22 mg Ni/m$^3$, by inhalation of a form of nickel sulphate hexahydrate aerosol for 104 weeks. NTP concluded that there was no evidence of carcinogenic activity (NTP, 1996c).

As summarized in a recent review (*TERA*, 1999), it has been suggested that the negative evidence from the NTP bioassays cannot be considered definitive. For example, as noted in that document, one line of reasoning is that insufficiently high concentrations were tested, although NTP did consider the testing to be adequate, and additional analysis showed that the lung tissue dose in the animal bioassay was comparable to that under occupational conditions, once particle size is taken into account.

In the nickel oxide inhalation study, rats were treated with 0, 0.5, 1.0 or 2.0 mg Ni/m$^3$ and mice with 0, 1.0, 2.0 or 3.9 mg Ni/m$^3$ for 104 weeks. NTP concluded that there was some evidence of an increased incidence of alveolar/bronchiolar adenoma or carcinoma or squamous cell carcinoma, and benign or malignant pheochromocytoma in rats. NTP concluded that there was no evidence of carcinogenic activity in male mice but equivocal evidence of alveolar/bronchiolar adenoma or carcinoma in female mice (NTP, 1996a).

The most complete analysis of pre-1990 epidemiology studies of nickel workers was carried out by the International Committee on Nickel Carcinogenesis in Man (ICNCM)(Doll et al., 1990). This study examined ten cohorts involving workers mining, smelting and refining nickel as well as workers in nickel related industries (metallic nickel powder and nickel alloy) (Inco, Clydach, Wales, Falconbridge, Ontario, Huntington, W. Va., Inco, Copper Cliff and Coniston, Sudbury, Ontario, Inco, Port Colborne, Ontario, Falconbridge, Kristiansand, Norway, Oak Ridge, Tenn., Outokumpu Oy, Finland, Societe le Nickel, New Caledonia and Henry Wiggin Alloy Co., Hereford, England). This report concluded that more than one form of nickel gives rise to lung and nasal cancer. While much of the respiratory cancer risk seen in nickel refinery workers could be attributed to mixtures of oxidic and sulfidic nickel at concentrations greater than 10 mg/m$^3$, there was evidence that oxidic nickel and soluble nickel were also associated with lung and nasal cancer risks. Respiratory cancer risks were related to soluble nickel exposures at concentrations in excess of 1 mg/m$^3$. Soluble nickel exposures may enhance risks associated with exposure to less soluble forms of nickel. There was no evidence that metallic nickel was associated with increased lung and nasal cancer risks.

The epidemiological studies reviewed by IARC (1990) and Doll et al., (1990) have several limitations. The principal limitation was the limited data related to concentrations of specific nickel species in the air within the facilities that were studied. Consequently, it was not possible to establish dose-response relationships for specific nickel species. Doll et al., (1990) noted that the conclusions of many of the epidemiological studies (with respect to lung tumours) were confounded by a lack of information about the smoking habits of the workers. It should be noted that several epidemiology studies (including updates of those in the Doll report) have been published since the completion of the Doll report *(TERA*, 1999).

Update reports for the Clydach, Wales refinery cohorts have been reported (Easton et al., 1992; Draper et al., 1994). Easton et al., (1992) confirm that cancer risks are largely confined to workers employed in the 1930s and earlier. The results suggest that nasal cancer risk is due to soluble nickel exposure and at least one other insoluble nickel species, possibly nickel oxide, contributes to this risk. Draper et al., (1994) suggests that the cessation of leaching the nickel matte with an arsenic containing sulfuric acid in the 1920s is associated with the cessation of the occurrence of of sinus/nasal cancers.

Julian and Muir (1996) examined cancer incidence in Ontario men employed by Inco and Falconbridge (also examined by Doll et al., 1990). Their study is further discussed in ODP (1997). An excess of laryngeal cancer was reported for employees not exposed to the sintering process. Underground miners were also shown to have a significant lung and nasal cancer excess for miners with greater than 25 years exposure. The prevalence of smoking among this cohort may have contributed to this excess lung cancer.

A morbidity update of the Kristiansand, Norway cohort (reviewed by Doll et al., 1990) was reported by Andersen (1992) and Andersen et al., (1996). Their analysis showed an excess risk of lung cancer in association with exposure to soluble forms of nickel. The study suggested a multiplicative effect of smoking and nickel exposure.

Pang et al., (1996) reported on the mortality of a small cohort of English nickel platers with no exposure to chromium. These workers were principally exposed to soluble nickel salts. No risk of occupational lung cancer was discerned. However, there was weak evidence that nickel plating is associated with an excess risk of stomach cancer.

The cohort of US high alloy nickel workers examined by Doll et al., (1990) was expanded and updated by Arena et al., (1998). An overall significant 13% increased risk for lung cancer was noted when compared to the total US population. However, no significant excess was identified when local populations were used.

Anttila et al., (1998) updated cancer incidence among workers at the Finnish smelter and refinery examined by Doll et al., (1990). Nickel compounds was statistically significant in smelter workers with a latency of greater than 20 years. Refinery workers exposed to nickel sulfate levels less than 0.5 mg/m$^3$ showed an increased risk for nasal cancer and an excess risk for stomach and lung cancer.

The epidemiology studies of nickel process workers published since Doll et al., (1990) generally support the conclusions of the ICNCM report and expand on the association of occupational exposure to elevated levels of nickel compounds and respiratory cancer. The role of soluble nickel species as a contributor to risks associated with exposure to insoluble nickel compounds is confirmed (Easton et al., 1992; Anttila et al., 1998). The association of soluble nickel exposure with excess stomach cancer risk is notable (Pang et al., 1996, Anttila et al., 1998). Further support for a multiplicative role for smoking and nickel exposure leading to excess lung cancer risk is also notable (Andersen et al., 1996; Julian and Muir, 1996; ODP, 1997). It should be noted also that nickel smelter and refinery workers had concomitant exposures to copper, cobalt, arsenic, lead, sulphuric acid mist and other substances depending on the type of nickel product being processed. The role of these other substances in nickel-related cancer incidence has not been addressed.

### A2-9.2.4 Contact Dermatitis

Contact or allergic dermatitis is an allergy to nickel following some sensitizing exposure in individuals who are nickel sensitive. A relationship between specific human lymphocyte antigens and nickel sensitivity has been observed (Mozzanica et al., 1990). Nickel dermatitis is the most commonly observed adverse effect of nickel. Asthma may occur in a small number of sensitized individuals (Dolovich et al., 1984; Novey et al., 1983; Shirakawa et al., 1990; as cited in ATSDR, 1997). This allergic response is manifested in two main ways. Sensitized individuals can react to nickel in subsequent dermal exposures, or, following oral exposures to nickel (Keczkes et al., 1982).

In non-occupational exposures, the primary exposure to nickel as a sensitizing event occurs primarily as a result of prolonged skin contact with nickel-containing metal objects (jewelry, coins, dental braces, stainless steel and metal fastenings on clothes) (Menne and Maibach, 1989; Menne et al., 1989; Wilkinson and Wilkinson, 1989) or when metal objects are inserted into body parts (ear piercing, orthodontics and orthopaedic devices) (Dotterud and Falk, 1994; Larsson-Stymne and Widstrom, 1985; Meijer et al., 1995; van Hoogstraten et al., 1991). Contact dermatitis may also result from occupational exposure (Liden, 1994). Once an individual has been sensitized to nickel, subsequent exposure (inhalation, ingestion or dermal contact) to low levels of nickel may cause a reaction (Keczkes et al., 1982). However, continued oral exposure to nickel has also been shown to desensitize some individuals and prevent sensitization in other cases (see later discussion).

Studies of Norwegian populations have indicated a prevalence range of 8 to 11% in females and approximately 1 to 2% in males (Nielsen and Menne,1993; Peltonen, 1979 as cited in Smith-Sivertsen et al., 1999). As studies have indicated that the most important known risk factor associated with nickel allergy is ear piercing (Nielsen and Menne, 1993), it is likely that gender differences in dermatitis prevalence can be explained primarily by differences in ear piercing habits and use of jewelry (Smith-Sivertsen et al., 1999).

Smith-Sivertsen et al., (1999) conducted a large study of Norwegian populations to evaluate the importance of local nickel pollution, as well as ear piercing and atopic dermatitis, on the prevalence of nickel allergy. A total of 1,767 adults were randomly selected from two different cross-sectional studies: i) in the town of Sør-Varanger, which is situated near a nickel smelter in the Russian city of Nikel, and; ii) in the town of Tromsø, which has no nearby nickel-polluting industries. Results of the study indicated that nickel allergy was very common among adults in both of the north-Norwegian study populations, and that despite the geographical closeness to the Russian nickel industry, inhabitants of Sør-Varanger did not have a higher prevalence than those living in the city of Tromsø. Interestingly, ear piercing in women demonstrated a more than three fold increased risk of being sensitized to nickel, and increased further with increasing number of holes in the ear lobes. Based upon comparisons of urinary nickel concentrations in each of the study populations, the authors concluded that a pollution-dependent increased risk of nickel allergy was unlikely, and that intimate skin contact with any object that releases nickel (eg., ear rings or jewelry) constitutes a much larger risk of primary sensitization or elicitation of dermatitis in individuals already nickel-sensitized (Smith-Sivertsen et al., 1999).

Skin contact with nickel appears to be facilitated by the release of nickel as a soluble form into sweat. Nickel must be in a soluble form in order to be absorbed into the skin through the horny layer. Sweat and friction facilitate this process. Normal sweat has a slightly acidic to neutral pH, and contains amino acids and salts containing chloride (ICRP, 1984, Casarett and Doull, 1991). The development of contact dermatitis after this type of contact with nickel occurs through a series of cellular skin responses, initiating the allergic reaction to nickel, and manifesting as contact dermatitis.

Dermal patch studies in sensitive individuals show a dose response relationship between the amount of nickel applied and the severity of the test response (Emmet et al., 1988; Eun and Marks, 1990). Most patch testing is done with nickel sulphate because it is less irritating, however, nickel chloride may be more biologically relevant (Menne, 1994) and has been shown to pass more rapidly through the upper layers of the skin (Fullerton et al., 1986). Studies of skin reactions with nickel chloride in sensitive individuals indicate that the NOAEL aqueous nickel concentration is about 300 ppm (Eun and Marks, 1990).

Other studies with nickel alloys tested for their release of nickel into synthetic sweat indicated weak reactivity at release rates < 0.5 µg/cm$^2$/week (or less than 0.07 µg/cm$^2$/day) (Menne et al., 1987). This information forms the basis for the 1994 European Union Directive forbidding the use of nickel in products placed in direct contact with the skin and to restrict release of nickel to less than 0.5 µg/cm$^2$/week during normal use for up to two years.

Flare up of skin reactions to nickel can occur in sensitized people following single oral exposures to nickel. The issue of allergic dermatitis following ingestion of nickel-containing food items has been reviewed (US FDA, 1993). In studies where nickel (mainly in a soluble form such as the sulphate) was administered orally to human subjects with chronic nickel dermatitis or eczema, single doses of 2,500 µg to 5,600 µg nickel produced aggravated reactions (Cronin et al., 1980; Kaaber et al., 1978; Gawkroder et al., 1986; Veien et al., 1983). One double blind study showed that a single 2,500 µg dose of orally administered nickel was sufficient to aggravate the chronic nickel dermatitis in 17 of the 28 patients tested (Veien et al., 1983). Other, less reliable studies suggest that as little as 600 µg or 1,250 µg of ingested nickel may exacerbate the skin conditions in patients with long standing (10-17 years) nickel sensitivity. In one double blind study (Jordan and King, 1979), one of the ten nickel hypersensitive patients tested consistently reacted to a 500 µg oral nickel challenge. Thus, oral nickel exposure of as little as 500 µg/day in addition to the diet may produce adverse reactions in some nickel hypersensitive persons. The lowest single dose resulting in dermatitis in sensitized individuals is about 0.009 mg/kg/day (Cronin et al., 1980). Other studies showed that a low incidence of allergic dermatitis responses occurred in the 0.02 to 0.04 mg/kg/day range (Burrows et al., 1981; Gawkroder et al., 1986; Kaaber et al., 1978; Menne and Maibach, 1987). This situation is complicated by studies that show that low nickel diets can prevent induction of nickel sensitivity (van Hoogstraten et al., 1991).

Oral hyposensitization (or de-sensitization) to nickel after various oral dose regimes is discussed in WHO (1998). This response was reported after six weekly doses of 5 mg of nickel in a capsule (Sjöwall et al., 1978) and 0.1 ng of nickel sulphate daily for three years (Panzani et al., 1995). Cutaneous lesions were improved in eight patients with contact allergy to nickel after oral exposure to 5 mg of nickel weekly for eight weeks (Bagot et al., 1995). Nickel in water (as nickel sulphate) was given to 25 nickel-sensitive women in daily doses of 0.01–0.04 mg/kg of body weight per day for three months after they had been challenged once with 2.24 mg of nickel (Santucci et al., 1988). In 18 women, flares occurred after the challenge dose, whereas only three out of 17 subjects had symptoms during the prolonged exposure period. Later, Santucci and co-workers (1994) gave increasing oral doses of nickel in water (0.01 – 0.03 mg of nickel per kg of body weight per day) to eight nickel-sensitive women for up to 178 days. A significant improvement in hand eczema was observed in all subjects after one month.

ATSDR (1997) also discusses the same studies of contact dermatitis following oral exposure and indicates that setting of oral exposure limits for nickel is complicated by the presence of sensitized individuals in the general population. Some of the induced reactions at very low levels of exposure indicate that individual characteristics may be at play. Given the literature showing both elicitation and de-sensitization of contact dermatitis following oral supplementation of ambient nickel levels in the diet and/or drinking water it may not be possible to set oral exposure limits based on contact dermatitis reactivation.

### A2-9.2.5 Susceptible Populations

Populations which are unusually susceptible to nickel are those people already sensitive to nickel due to prolonged contact with nickel. Subsequent exposures may result in an allergic reaction. A greater number of women tend to be sensitized to nickel than men and this is believed to be related to the fact that woman tend to wear more metal jewelry than men. Further study is required to determine whether there is indeed a gender difference in nickel sensitivity. Persons with kidney dysfunction are also likely to be more susceptible to nickel as the primary route of nickel elimination is via the urine.

## A2-9.3 Current Exposure Limits

It should be noted that the Health Canada (1996) exposure limits for nickel compounds cited below are based on toxicological literature reviewed up to 1993. Several key studies have been published since 1993 (*TERA*, 1999, WHO, 1998, WHO, 2000 and IOM, 2001).

### A2-9.3.1 Nickel Refinery Dusts and Nickel Subsulphide

Inhalation

The inhalation exposure limits for the three majors agencies and their derivation is described below. Neither US EPA, Health Canada nor WHO state their limits as µg Ni/m$^3$ or risk per µg Ni/m$^3$. Doll et al., (1990) does specific airborne Ni levels as such. It may be reasonably assumed that the nickel refinery worker personal air samplers were analysed using a total Ni approach and that nickel speciation was imposed retroactively, the implication is that the analytical data is total Ni and no further conversion is needed.

US EPA

Nickel refinery dusts and nickel subsulphide are both classified by the US EPA as group A: human carcinogens (US EPA, 1998 - carcinogenic assessments last revised 1991). Only inhalation unit risk values for these substances are available. The US EPA quantitative inhalation risk estimates are based on epidemiological studies of four nickel refineries (Huntington, W. Va., Inco, Copper Cliff, Ontario, Inco, Clydach, Wales and Falconbridge, Kristiansand, Norway) (US EPA, 1986). These cohorts were selected from a review of 18 industrial facilities involving workers mining, smelting, and refining nickel as well as workers in nickel related industries (metallic nickel powder, nickel alloy, electroplating, nickel-cadmium battery and stainless steel welding).

A cohort of employees of a nickel refinery in West Virginia who experienced a minimum one year exposure to nickel refinery dusts (containing nickel subsulphide, sulphate and oxide or only nickel oxide) did not show an increased incidence of lung cancer above expected rates (Enterline and Marsh, 1982). Chovil et al., (1981) studied a cohort of nickel refinery workers in Ontario, and observed a dose-related trend for the relationship between weighted exposure in years to the incidence of lung cancer. Similarly, a cohort of Welsh nickel refinery workers had elevated risks of cancer compared to the national average. Increased rates of nasal cancer were observed in men employed prior to 1920, while this rate was less than the national average for those starting work between 1920 and 1925, and equaled the expected value for those employed after 1925 (Doll et al., 1977). A significantly increased lung cancer related mortality was observed in employees starting prior to 1925 but not in those starting between the years 1930 to 1944. Pedersen et al., (1973) conducted a study of men employed at a nickel refinery in Norway, and reported an elevated occurrence of respiratory cancer for nickel exposed workers compared to expected values, and for workers involved in nickel processing steps compared to non-processing employees.

Two dose-response models (the excess additive risk model and the multiplicative or relative risk model) were evaluated. Two main assumptions were necessary:

1. For particulates such as nickel subsulphide and nickel refinery dust with relatively long lung clearance times, the cancer response was some function of a cumulative dose or exposure;

2. The magnitude of the response is a linear function of the cumulative dose.

The estimates of incremental unit risks for lung cancer due to exposure to 1 $\mu g$ Ni / $m^3$ as nickel refinery dust for a life-time using either model ranged from $1.1 \times 10^{-5}$ to $4.6 \times 10^{-4}$. The mid point of this range is $2.4 \times 10^{-4}$. Since nickel subsulphide was believed to be a major component of nickel refinery dust (roughly 50%) and the animal evidence at that time showed nickel subsulphide to be the most carcinogenic compound tested, US EPA recommended that the nickel refinery dust unit incremental risk estimate multiplied by two could be used for nickel subsulphide.

For nickel subsulphide, the inhalation unit risk is $4.8 \times 10^{-4}$ $(\mu g/m^3)^{-1}$ (US EPA, 1998 - carcinogenic assessment last revised 1991).

### Health Canada

Health Canada (1996) has classified oxidic, sulphidic and soluble nickel as Group I (Carcinogenic to Humans). This group includes nickel oxide, nickel copper oxide, nickel silicate oxides and complex oxides, nickel sulphide, nickel sulphate and nickel chloride. This classification is based on the studies of Doll et al., (1990) and the International Agency for Research in Cancer (IARC) evaluation (IARC, 1990).

Health Canada (1996) has developed an inhalation tumorigenic concentration ($TC_{05}$) of 0.04 $mg/m^3$ for *combined* oxidic, sulphidic and soluble nickel. This $TC_{05}$ is based on the studies of nickel refinery workers and workers exposed to metallic nickel powder or nickel alloys (Doll et al., 1990)(see section A2-9.2.3). Health Canada selected two large cohorts of exposed workers from Doll et al., (1990) for whom exposure information was available (Inco, Copper Cliff, Ontario, and Falconbridge, Kristiansand, Norway). The $TD_{05}$ for lung cancer mortality for soluble nickel is 0.07 $mg/m^3$ (CEPA, 1994, Hughes et al., 1994, Health Canada, 1996).

Health Canada (1996) reports a non-cancer tolerable inhalation concentration of 0.018 $\mu g/m^3$ for nickel subsulphide.

## WHO

WHO (1987) developed an incremental unit risk of $4 \times 10^{-4}$ per $\mu g / m^3$ for nickel subsulphide based on three epidemiological data sets for nickel refinery workers: the Kristiansand, Norway data (Magnus et al., 1982, the Copper Cliff, Ontario data (Chovil et al., 1981), and the Clydach, Wales data (Doll et al., 1977). The incremental unit risks for lung cancer calculated from each data set ranged from $1.5 \times 10^{-4}$ to $5.9 \times 10^{-4}$ per $\mu g / m^3$. The geometric mean of these three risk estimates was $4 \times 10^{-4}$ per $\mu g / m^3$.

WHO (2000) reassessed this unit risk for lung cancer using updated epidemiology data from workers at the Kristiansand, Norway refinery first employed between 1968 and 1972 and followed through to 1987 (Andersen, 1992, Andersen et al., 1996). An incremental life-time unit risk of $3.8 \times 10^{-4}$ per $\mu g / m^3$ was calculated using an estimated risk of 1.9 for this group and an exposure estimate of 2.5 $\mu g / m^3$ resulting in a life-time exposure of 155 $\mu g / m^3$. The WHO air quality guideline does not specify what form(s) of airborne nickel are addressed.

## Discussion

It is interesting to note that the lung cancer based inhalation exposure limits based on nickel mining, smelting and refining operations in North America, Wales and Norway, which were included in the WHO's, Health Canada's and the US EPA's derivation of quantitative risk estimates result in cancer potency estimates that are approximately five fold different. These differences in inhalation cancer potencies can be attributed to the use of different epidemiology data from the cohorts selected, and mathematical extrapolation procedures. The US EPA used the mid point of the range of maximum likelihood estimates (MLE) of a relative risk model from two risk models and for workplace data sets (US EPA, 1986).

WHO (2000) does not specify a confidence interval for their linear extrapolation from a single workplace data set. Health Canada also does not specify a confidence interval and used a model based on an exponential function of the cumulative exposure to total nickel from three Canadian workplace data sets and the Norwegian data (CEPA, 1994; Hughes et al., 1994).

In a paper describing Health Canada's approach to characterizing carcinogenic potency and development of the $TD_{05}$, it is stated: "any model that fits the empirical data well is likely to provide a reasonable estimate of the potency; choice of the model may not be critical since estimation is within the observed range, thereby avoiding the numerous uncertainties associated with low dose extrapolation" (Meek et al., 1994). A footnote in the same paper states, "the $TD_{05}$ is not based on the confidence limit but rather, is computed directly from the curve. This was considered to be appropriate in view of the stability of the data in the experimental range and to avoid unnecessary conservative assumptions. Also, use of a point estimate or confidence limit does not affect the relative magnitude of the potency estimates for different compounds". Extrapolation of the $TC_{05}$ to negligible risk levels ($10^{-5}$ to $10^{-6}$) is assumed to be strictly linear (Health Canada, 1996), whereas the US EPA unit cancer risk used a different mathematical extrapolation.

Ingestion

No ingestion exposure limits for nickel refinery dusts and nickel subsulphide were located.

### A2-9.3.2 Nickel Soluble Salts

Inhalation

For the inhalation route, Health Canada (1996) recommends a tolerable inhalation concentration (non-cancer effects) of 0.0035 µg/m$^3$ for nickel sulphate. The TC was based on a subchronic study of lung and nasal lesions in rats and mice observed by Dunnick et al., (1989). *TERA* (1999) have developed an inhalation R*f*C of 0.2 µg/m$^3$ based on a benchmark concentration ($BMC_{10}$) for lung fibrosis in rats.

Health Canada developed a $TC_{05}$ for lung cancer mortality for soluble nickel (mainly nickel sulphate and nickel chloride) of 0.07 mg/m$^3$. This $TC_{05}$ is based on data from a cohort in Norway (Doll et al., 1990).

ATSDR (1997) has developed a chronic MRL for inhalation exposure of $2 \times 10^{-4}$ mg/m$^3$ (0.2 µg/m$^3$) based on a study of nickel sulphate hexahydrate inhalation in rats (NTP,1996c).

Ingestion

The US EPA (US EPA IRIS, 1998 - oral R*f*D assessment last revised 1996) recommended an oral R*f*D of 20 µg/kg/day for soluble salts of nickel based on decreased body and organ weight data in two year dietary study in rats (Ambrose et al., 1976). This R*f*D was originally placed on IRIS in 1988 and may not necessarily protect the already sensitized individual.

For nickel sulphate, Health Canada (1996) derived a TDI of 50 µg/kg/day, based on the NOAEL from the Ambrose et al., (1976) two year dietary study in rats.

WHO (1998) re-evaluated and maintained their drinking water quality guideline for nickel of 0.02 mg/L, but state that this value is considered provisional owing to uncertainties about the effect level for perinatal mortality (in rats). WHO (1998) refers to a recent, well conducted two generation study on rats exposed to nickel chloride in drinking water with a LOAEL for litter mortality of 1.3 mg nickel/kg body weight/day in the second litter (Smith et al., 1993). However, Smith et al., (1993) is a one generation, two litter study not a two generation study.

Earlier descriptions of this WHO drinking water quality guideline refer to a TDI of 5 μg nickel/kg/day (WHO, 1993, 1996). This TDI is described as being based on a dietary study in rats fed nickel chloride that showed a NOAEL of 5 mg/kg/day for altered organ-to-body-weight ratios (Ambrose et al., 1976) and was derived using an overall uncertainty factor of 1,000. This uncertainty factor was made up of 100 for inter and intraspecies variation. An additional factor of ten was to compensate for the lack of adequate studies on long term toxicity and reproductive effects, the lack of data on carcinogenicity by the oral route, and a much higher intestinal absorption when taken on an empty stomach in drinking water than when taken together with food. The earlier derivation of the WHO drinking water quality guideline allocated 10% of this TDI to drinking water exposure to derive 0.02 mg/L. In addition, it was stated that this drinking water guideline should provide sufficient protection for nickel-sensitive individuals (WHO, 1993, 1996).

It is of note that this TDI is not referenced in the 1998 WHO re-evaluation of its drinking water quality guideline, nor, is there any further description of this TDI elsewhere in the WHO literature. Since the 1998 WHO re-evaluation of its drinking water quality guideline for nickel discusses different animal studies than the 1993 and 1996 evaluations, the status of this TDI is unclear.

ATSDR (1997) did not determine oral MRLs for nickel because the protection of sensitized individuals and application of uncertainty factors to the LOAEL for contact dermatitis (0.009 mg/kg/day, Cronin et al., 1980) would result in an MRL which would bring the dose below normal dietary intake (about 0.002 mg/kg/day in the US).

Health Canada (1996) developed a TDI for soluble nickel of 1.3 μg Ni/kg body weight/day. This is based on a LOAEL of 1.3 mg/kg/day for an increased proportion of dead pups per litter in a one generation, two litter study of rats administered nickel chloride in drinking water (George et al., 1989; Smith et al., 1993). This TDI was derived using a overall 1,000-fold uncertainty factor which was based on ten fold for intraspecies variation, ten fold for interspecies variation and ten fold because a LOAEL rather than a NOAEL was observed.

The US National Academies' Institute of Medicine report on Dietary Reference Intakes (DRI) (IOM, 2001) did not have enough data to define whether there was a beneficial role for nickel and therefore did not establish recommended intake levels. However, based on adverse effect levels in animal studies, tolerable upper intake levels were set for nickel at 1 mg/day for adults and 0.2 mg/day for one to three year old children. DRIs expand on Recommended Dietary Allowances (RDAs) in the US and Recommended Nutrient Intakes in Canada. This tolerable upper intake level (UL) for nickel represents about 17 μg Ni/kg/day for a 61 kg female adult. The UL for one three year old children represents about 15 μg Ni/kg/day for a 13.3 kg US toddler. The UL applies to soluble nickel salt intake in excess of nickel consumed in a normal diet. The mean dietary nickel consumption of US infants and young children is cited as 69 to 90 μg/day (US FDA Total Diet Study, as cited in IOM, 2001) or 190 to 251 μg/day for Canadian children (Dabeka and McKenzie, 1995). For adults US dietary nickel intakes are cited as 74 to 100μg/day and 207 to 406 µg/day for Canadians. The median supplemental intake for adult men and women was approximately 5 µg/day.

IOM (2001) used oral subchronic and chronic rat studies (ABC, 1988, Ambrose et al., 1976) to identify a NOAEL of 5 mg/kg/day for soluble nickel salts. An overall uncertainty factor of 300 was used, which Incorporated a UF of ten for rat to human extrapolation, a second UF of ten for variation in human population, including uncertainties in nickel hypersensitivity in sensitive individuals, and a third UF of three because of uncertainties raised by studies of reproductive effects (in animals) and whether reproductive effects may occur at levels lower than the NOAEL (IOM, 2001).

IOM (2001) identified three animal reproduction studies (Schroeder and Mitchener, 1971, RTI, 1988, and Smith et al., 1993). The lowest LOAEL identified was 1.3 µg/kg/day (Smith et al., 1993) based the number of dead pups in a litter. All of the reproduction studies were considered flawed or difficult to interpret due to their statistical design, and limitations in methodology and data reporting, and not suitable for use in establishing a UL.

The ingestion exposure limits for soluble forms of nickel are summarized in Table A2-14. Refer to Section A2-9.2.2 for further information on the toxicity studies cited in this Table. The derivation and application of uncertainty factors to toxicity endpoints is further discussed in Section A2-1.

## Table A2-14: Survey of the Rationales for Soluble Nickel Exposure Limits Developed by Major Agencies

| R*f*D (µg/kg/day) | Study Selected | NOAEL/LOAEL/UF | Agency |
|---|---|---|---|
| 50 (nickel sulphate) | Based on decreased body and organ weight data in two year dietary nickel sulphate study in Wistar rats (Ambrose et al., 1976) | NOAEL = 5 mg Ni/kg/day<br>UF = 100<br>X10 for interspecies variation<br>X10 for intraspecies variation | Health Canada (1996) |
| 20 (soluble salts)<br>Total nickel intake | Based on 1) decreased body and organ weight data in two year dietary nickel sulphate study in Wistar rats (Ambrose et al., 1976), and, 2) haematological effects in a 90 day study of nickel chloride in drinking water administered by gavage to CD rats (ABC, 1988) | NOAEL = 5 mg Ni/kg/day<br>UF = 300<br>X10 for interspecies variation<br>X10 to protect sensitive populations<br>X3 for inadequacies in reproductive studies | US EPA IRIS (1998) |
| Tolerable upper intake level intake in excess of the normal US diet (soluble salts)<br>17 for adult female (61 kg);<br>15 for 1-3 yrs US toddler = 13.3 kg | Based on 1) decreased body and organ weight data in two year dietary nickel sulphate study in Wistar rats (Ambrose et al., 1976), and, 2) haematological effects in a 90 day study of nickel chloride in drinking water administered by gavage to CD rats (ABC, 1988) | NOAEL = 5 mg Ni/kg/day<br>UF = 300<br>X10 for interspecies variation<br>X10 to protect sensitive populations<br>X3 for inadequacies in reproductive studies (in animals) and whether reproductive effects may occur at levels lower than the NOAEL | (IOM, 2001) |
| 5 (nickel sulphate)<br>Total nickel intake | Based on decreased body and organ weight data in two year dietary nickel sulphate study in Wistar rats (Ambrose et al., 1976) | NOAEL = 5 mg Ni/kg/day<br>UF = 1,000<br>X10 for interspecies variation<br>X10 for intraspecies variation<br>X10 for insufficient studies for long term toxicity and reproductive effects, lack of data on carcinogenicity by the oral route, and higher intestinal absorption when taken in drinking water on an empty stomach | WHO (1996) |

| R*f*D (µg/kg/day) | Study Selected | NOAEL/LOAEL/UF | Agency |
|---|---|---|---|
| ? = not specified (studies involving nickel sulphate and nickel chloride) Total Nickel intake and Nickel intake in addition to diet | Based on 1) decreased body and organ weight data in two year dietary nickel sulphate study in Wistar rats (Ambrose et al., 1976); 2) mainly haematological changes in several subchronic studies in rats, and, a 90 day study of rats administered nickel chloride in drinking water (RTI, 1988 described in Velazquez and Poirier, 1994, ATSDR, 1997), and 3) increased pup mortality in a one generation, two litter reproduction study of female Long Evans rats treated with nickel chloride in drinking water for 11 weeks prior to and during two successive gestational periods (Smith et al., 1993) | 1) NOAEL = 5 mg Ni/kg/day<br>2) NOAEL = 10, 10 and 5 mg Ni/kg/day<br>3) LOAEL = 1.3 mg Ni/kg/day<br>Not stated, probably 1,000 | WHO (1998) |
| 1.3 (nickel chloride) | Increased pup mortality in a 1-generation, 2 litter reproduction study of female Long Evans rats treated with nickel chloride in drinking water for 11 weeks prior to and during two successive gestational periods (Smith et al., 1993) | LOAEL = 1.3 mg Ni/kg/day<br>UF = 1,000<br>X10 for interspecies variation;<br>X10 for intraspecies variation;<br>X10 for LOAEL rather than NOAEL | Health Canada (1996) |
| **Studies selected for review** | | | |
| Eight (nickel soluble salts ) Nickel intake in addition to diet | Based on increased albuminuria in Wistar rats administered nickel sulphate in drinking water for six mo. (Vyskocil et al., 1994) | LOAEL = 7.6 mg Ni/kg/day<br>UF = 1,000<br>X10 for interspecies variation<br>X10 for intraspecies variation<br>X10 for subchronic to chronic extrapolation, insufficient database and use of a LOAEL | *TERA* (1999) sponsored by US EPA, Health Canada and the Metal Finishers of Southern California |
| 22 (nickel sulphate) | Based on a NOAEL for parental survival, growth, mating behavior, fertility, implantation, gestation length, and post-implantation/perinatal lethality in a two generation reproduction study of Sprague Dawley rats administered nickel sulphate by gavage (Springborn, 2000) | NOAEL = 2.2 mg Ni/kg/day<br>UF = 100<br>X10 for interspecies variation<br>X10 for intraspecies variation | Springborn (2000) sponsored by NiPERA and under review by US EPA |

### A2-9.3.3 Nickel Oxide

Inhalation

A tolerable inhalation concentration ($TC_{05}$) (non-cancer effects) of 0.02 $\mu g/m^3$ based on changes in alveolar macrophages, granulocytes and lymphocytes in rat lungs (Spiegelberg et al., 1984) has been developed (Health Canada, 1996).

Health Canada (1996) has classified oxidic nickel (including nickel oxide, nickel copper oxide, nickel silicate oxides and complex oxides as Group I (Carcinogenic to Humans). This classification is based on the studies of Doll et al., (1990) and the International Agency for Research in Cancer (IARC) evaluation (IARC, 1990).

It should be clarified that all toxicological information regarding the carcinogenicity of nickel oxide, either as a component of nickel refinery dusts or as a pure compound administered to rats and mice is only by the inhalation route. In addition, while nickel oxide has carcinogenic potential when inhaled (based on human and animal studies), there are no published inhalation unit cancer risks by which to assess its potency.

Ingestion

There is no information regarding its carcinogenicity via the ingestion route in humans or animals.

### A2-9.3.4 Metallic Nickel

Inhalation

Health Canada (1996) classified metallic nickel as Group IV (unclassifiable with respect to carcinogenicity in humans). Health Canada (1996) reports a provisional non-cancer tolerable concentration (inhalation) of 0.018 $\mu g/m^3$.

Ingestion

No ingestion exposure limits for metallic nickel were located.

### A2-9.3.5 Dermal Exposure Limits

Contact dermatitis caused by nickel exposure is discussed in section A2-9.2.4, above.

The European Directive 94/27/EC (European Union, 1994) of June 30, 1994 addresses the issue of (metallic) nickel in certain objects (mainly jewelry, but including clothes fasteners) coming into direct and prolonged contact with the skin and causing sensitization and allergic responses in humans. This directive requires that:

(1) jewelry that pierces the skin must contain less than 0.05% nickel (500 µg/g) on a mass basis;
(2) products coming into direct and prolonged contact with the skin are restricted to release nickel at a rate of less than 0.5 µg/cm$^2$/week;
(3) products listed in (2) with a non-nickel coating must also ensure that the nickel release rate not exceed 0.5 µg/cm$^2$/week for at least two years normal usage of the product.

This directive is not directly applicable to the situation where soil nickel gets on the skin.

### A2-9.3.6 Selection of Exposure Limits

Inhalation

To assess the potential for cancer effects related to inhalation of nickel oxide, the annual average ambient air concentration (TSP sampler) from MOE monitoring station 27047 (at Davis and Fraser) data was compared to inhalation life-time cancer risk factors from various agencies (tabulated in Table A2-14). These inhalation unit risks may not be based on respirable nickel compounds since total airborne nickel was measured in the workplace. TSP sampler data is the most comparable data for use with workplace exposure data.

Ingestion

For the purposes of this risk assessment, the US EPA R*f*D for soluble nickel was selected to assess potential non-cancer effects from estimated nickel intakes from all exposure routes. This is essentially the same exposure limit as the tolerable upper intake level for soluble nickel recently derived by IOM (2001).

Other considerations include:

> Other oral exposure limits below this value were generally below normal dietary intake estimates (Dabeka and McKenzie, 1995). Since some of these exposure limits are directed towards intakes supplemental to diet, eg., drinking water intakes, they are unsuited for total exposure considerations.
>
> Any exposure limit for soluble nickel has to consider the oral hypersensitivity of some nickel sensitized people. This may be offset by other studies showing that nickel supplements can lead to hyposensitization of other sensitized people (section A2-9.2.4).
>
> There is difference of opinion on the suitability of some reproductive studies involving nickel chloride administered in drinking water for use in deriving exposure limits (section A2-9.2.2).

As stated in chapter 3 and section A2-1, the development of new exposure limits was not considered. Each toxicity study used to support exposure limits (R*f*D, TDI, etc.), has been subjected to detailed evaluation and review by the agency involved and some discussion of the reliability, strengths and weaknesses and confidence rating of the studies can be found (US EPA, 1998 - oral R*f*D assessment last revised 1996, CEPA, 1994, Hughes et al., 1994, WHO, 1996, 1998, IOM, 2001). For the chronic toxicity and reproductive toxicity studies selected to support exposure limits, the NOAEL/LOAEL range is 1.3 mg/kg/day (LOAEL, Smith et al., 1993) to 5 mg/kg/day (NOAEL, Ambrose et al., 1976, ABC, 1988) (Table A2-14). Other assessments have considered basing R*f*Ds on values ranging from 2.2 mg/kg/day (NOAEL, Springborn, 2000) to 7.6 mg/kg/day (LOAEL, *TERA*, 1999 and Vyskocil et al., 1994) (section A2-9.2.2). In conjunction with UFs of 10 X ten fold for inter and intra species extrapolation, additional UFs have been used to account for other shortcomings or deficiencies in the supporting study selected (this is discussed in section A2-1).

For the studies selected to develop ingestion exposure limits for soluble nickel, the NOAEL for chronic toxicity of 5 mg/kg/day is well established (Ambrose et al., 1976). This NOAEL value was recently endorsed by IOM (2001). Lack of a defined NOAEL for reproductive toxicity is a data gap which has required the use of an additional UF due to uncertainty about the NOAEL for this endpoint (WHO, 1996, Health Canada, 1996). The new unpublished study of Springborn (2000) is currently under review by US EPA as part of a re-assessment of the 1988 R*f*D for soluble nickel ingestion on IRIS (Ambika Bathija - personal communication). Springborn (2000) demonstrates a clear NOAEL for reproductive toxicity. This suggests that a UF to account for this data gap may no longer be necessary or that the magnitude of the UF adjusting for lack of this information can be revised resulting a smaller overall UF. Consequently, the NOAEL and UFs used in the US EPA R*f*D for soluble nickel continue to provide an adequate margin of safety to protect human health.

**Table A2-15: Selected Exposure Limits for Nickel Compounds**

| Route of Exposure | Exposure Limit | Toxicological Basis | Source Agency |
|---|---|---|---|
| Non-Cancer Effects | | | |
| Ingestion | 20 µg Ni/kg-day | reproductive effects and decreased body and organ weight in rats | US EPA, 1998, IOM, 2001 |
| Inhalation | - | - | - |
| Dermal Contact | - | - | - |
| Cancer Effects | | | |
| Ingestion | N.A.[1] | - | - |
| Inhalation[2] | $2.4 \times 10^{-4}$ (µg/m$^3$)$^{-1}$;<br>$3.8 \times 10^{-4}$ (µg/m$^3$)$^{-1}$ and $TC_{05}$ (0.04 mg/m$^3$) | lung cancer in nickel refinery workers | US EPA, 1998;<br>WHO, 2000 and Health Canada, 1996 |
| Dermal Contact | N.A. | - | - |

1. Not Applicable

2. Neither US EPA, Health Canada nor WHO state their limits as µg Ni/m$^3$ or risk per µg Ni/m$^3$. Doll et al., (1990) does specify airborne Ni levels as such. It may be reasonably assumed that the nickel refinery worker personal air samplers were analysed using a total Ni approach and that speciation was imposed retroactively, the implication is that the analytical data is total Ni and no further conversion is needed.

### A2-9.4 Nickel References

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# Appendix 3

## Detailed Estimates of Daily Intakes of Metals

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## A3-1 Assessing Exposures to Metals

Each of the exposure pathways identified in Section 4.1 of the main report, that can contribute to the total daily metal exposures experienced by the residents of the Rodney Street community, is discussed below. The method of calculation is presented, identifying all of the receptors and site-specific parameters that are considered for each pathway. Exposures are assessed for all of the receptors identified in Section 4.1 of the main report, and were estimated using the receptor parameters listed in Table 4-3 of the main report and discussed in Appendix 6.

### A3-1.1 Intake of Metals from Supermarket Food

Estimates of the daily dietary intakes of metals from supermarket foods are generally limited and the amount of information available varies widely between metals. The metals of concern in the Rodney Street community addressed in this exposure assessment include, antimony, beryllium, cadmium, cobalt, copper and nickel. Information regarding daily dietary intakes of these metals has been taken from Canadian and international regulatory agencies. Additional information has been taken from the available literature. For the purposes of assessing likely daily dietary metal intakes for the residents of the Rodney Street community, preference has been given to data generated from the Canadian population. It was felt that information from Canadian sources would provide the best reflection of likely dietary habits and metal intakes for residents of the Rodney Street community. The daily dietary intake of metals is discussed in detail in Appendix 4. A summary of the daily dietary intake of metals for all age groups is presented in Table A3-1.

**Table A3-1: Estimated Daily Intakes of Metals from Supermarket Food**

| Receptor | Daily Intakes of Metals from Supermarket Food (µg/day) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Infant | 1.3 | 4.8 | 5.08 | 4.18 | 518 | 109.2 (72.2-146.2)* |
| Toddler | 2.3 | 8.6 | 10.6 | 7.0 | 822 | 190 |
| Child | 3.5 | 13.2 | 16.8 | 10.0 | 1230 | 251 |
| Teen | 4.0 | 15.0 | 17.3 | 12.0 | 1520 | 313 |
| Adult | 3.4 | 12.7 | 14.8 | 10.0 | 1430 | 307 |
| Reference | FSA, 1997 | Vaessen & Szteke, 2000 | CEPA, 1994a | Dabeka & McKenzie, 1995 | CCME, 1997 | Dabeka, 1989; Dabeka & McKenzie, 1995 |

*see table A4-4

### A3-1.2 Intake of Metals from Drinking Water

Daily intakes of metals from drinking water are dependent on the amount of drinking water consumed on a daily basis and the level of metals present in the drinking water. The estimated intakes of metals from drinking water for the Rodney Street community has been calculated as shown in equation A3-1. Estimates of the intake of antimony, beryllium, cadmium, cobalt, copper and nickel from the consumption of drinking water for all age groups are shown in Table A3-2.

**EQ A3-1:**

$$Intake_{dw} = IR_{dw} * C_{dw}$$

| | | | | |
|---|---|---|---|---|
| Where: | $Intake_{dw}$ | = | Intake from drinking water | µg/day |
| | $IR_{dw}$ | = | Ingestion rate of drinking water | L/day |
| | $C_{dw}$ | = | Metal concentration in drinking water | µg/L |

The intake estimates are based on the highest level of each metal reported by the monitoring of drinking water taken from the municipal system at Charlotte Street. Although water quality was also measured at the treatment plant, the data from within the distribution system was felt to be more representative of the water quality in the Rodney Street community. The data in Table A3-2 shows that for most metals, daily intakes from drinking water are generally less than 1 µg/day. The most notable exception to this is copper, where intakes from drinking water range between 13 µg/day for infants and 66 µg/day for adults. For infants and toddlers, intakes of nickel from drinking water are below 1 µg/day, but intakes for children, teens and adults are greater than 1 µg/day. These values will be used in conjunction with intakes from other sources to provide estimates of total daily exposure for people in all age groups.

**Table A3-2: Estimated Metal Intakes from Drinking Water**

| Metal | Receptor | $C_{dw}$ (µg/L) | $IR_{dw}$ (L/day) | $Intake_{dw}$ (µg/day) |
|---|---|---|---|---|
| Antimony | 0 - 6 months | 0.97 | 0.3 | 0.29 |
| | 7 months - <5 years | 0.97 | 0.6 | 0.58 |
| | 5 - <12 years | 0.97 | 0.8 | 0.78 |
| | 12 - <20 years | 0.97 | 1 | 0.97 |
| | 20 + years | 0.97 | 1.5 | 1.5 |
| Beryllium | 0 - 6 months | 0.20 | 0.3 | 0.06 |
| | 7 months - <5 years | 0.20 | 0.6 | 0.12 |
| | 5 - <12 years | 0.20 | 0.8 | 0.16 |
| | 12 - <20 years | 0.20 | 1 | 0.20 |
| | 20 + years | 0.20 | 1.5 | 0.30 |
| Cadmium | 0 - 6 months | 0.083 | 0.3 | 0.025 |
| | 7 months - <5 years | 0.083 | 0.6 | 0.050 |
| | 5 - <12 years | 0.083 | 0.8 | 0.066 |
| | 12 - <20 years | 0.083 | 1 | 0.083 |
| | 20 + years | 0.083 | 1.5 | 0.12 |
| Cobalt | 0 - 6 months | 0.040 | 0.3 | 0.012 |
| | 7 months - <5 years | 0.040 | 0.6 | 0.024 |
| | 5 - <12 years | 0.040 | 0.8 | 0.032 |
| | 12 - <20 years | 0.040 | 1 | 0.040 |
| | 20 + years | 0.040 | 1.5 | 0.060 |
| Copper | 0 - 6 months | 44 | 0.3 | 13 |
| | 7 months - <5 years | 44 | 0.6 | 26 |
| | 5 - <12 years | 44 | 0.8 | 35 |
| | 12 - <20 years | 44 | 1 | 44 |
| | 20 + years | 44 | 1.5 | 66 |

| Metal | Receptor | $C_{dw}$ (µg/L) | $IR_{dw}$ (L/day) | $Intake_{dw}$ (µg/day) |
|---|---|---|---|---|
| Nickel | 0 - 6 months | 1.3 | 0.3 | 0.39 |
| | 7 months - <5 years | 1.3 | 0.6 | 0.78 |
| | 5 - <12 years | 1.3 | 0.8 | 1.0 |
| | 12 - <20 years | 1.3 | 1 | 1.3 |
| | 20 + years | 1.3 | 1.5 | 2.0 |

### A3-1.3 Intake of Metals from Ambient Air

Unlike other environmental media, such as soil or water, air quality may fluctuate from day to day or hour to hour, and exposure levels are also influenced by changes in meteorological conditions. To protect the general population against contaminants in outdoor air, on a continuous basis, time periods such as 24 hours or annual are used. These prescribed time periods are referred to as "averaging times" and are an important aspect of controlling air quality. This also has significance from a toxicological perspective since the dose of a chemical, which is time dependent, is a major determinant of toxicological effects. One consideration in establishing averaging time is to limit exposure peaks for airborne chemicals, which could occur within a long averaging period, such as a year.

Averaging time can be used to ensure protection against the different effects of airborne chemicals by ensuring that exposure limits for specific effects, acute or chronic, are not exceeded. Short term acute effects are normally based on a one hour (or less) exposure period while longer term chronic effects are based on a 24 hour or annual averaging time. Averaging times also provide useful benchmarks to monitor ambient air quality.

The time taken for chemical exposure to cause adverse health effects varies among chemicals and even a single chemical can cause different effects at different doses. Chemicals such as sulphur dioxide, may trigger an effect within 15 minutes, or less, of exposure. Others, such as the carcinogenic chemicals, may have a longer term cumulative effect, which may not clinically manifest for several years. The times over which concentrations should be averaged to reflect the time frame during which their effects become apparent varies, and averaging times are often set to reflect this.

Air monitoring data is usually collected on air samplers over relatively short time periods, eg., one to two days, and the results integrate the chemical concentration over the volume of air filtered and the time period the sampler was running. A single air sample would result in the air concentration over a daily time period. In the course of a year, if sufficient "daily" samples are taken, an annual average air concentration can be calculated. This way a picture of the peak levels and the overall average concentration in the air over the year can be constructed.

In Ontario, the Ministry of the Environment (MOE) has established air quality standards (air standards) including ambient air quality criteria (AAQC) and point of impingement (POI) standards. Ambient air quality criteria are established to protect human health and the environment (terrestrial vegetation and wildlife), and to prevent aesthetic impacts such as odor, soiling of property and visibility. The AAQC are used to assess the quality of the ambient environment, while POI standards are used to evaluate the impacts of airborne emissions.

AAQC are developed to protect the most sensitive sub-populations, with consideration of the most sensitive adverse effect(s) induced by the exposure to a pollutant. These criteria are derived from the most reliable and up-to-date scientific, toxicological and epidemiological information obtained from peer reviewed literature or from the studies from which other environmental protection agencies derive their respective air guidelines. In some occasions, AAQC can be derived based on the scientific rationale of occupational exposure limits. However, occupational exposure limits are developed to protect the safety of workers and their derivation may include science/policy decisions which may not be directly applicable to environmental health decision making.

Cancer risk is in general considered the likelihood of developing this disease as a result of a life-time exposure of an individual to low doses of a carcinogenic substance. Most of the cancer-based guidelines are derived from cancer slope factors which are mathematical estimates of additional or excess risk. Cancer risk-specific exposure concentrations can be derived from the slope factors. Cancer risk can also be expressed as the probability of developing this disease at a risk-specific exposure concentration, such as one case in a population of one million, one-hundred thousand or ten thousand. In line with risk levels considered for other MOE environmental programmes, the Ministry has adopted the risk level of one in a million to derive an annual average AAQC for carcinogens. Corresponding air standards for other averaging times such as the 24 hour average AAQC and the half hour POI can be derived mathematically based on a power law equation and the scaling factors are as follows:

24 hour average AAQC = annual AAQC x 5
half hour POI limit = annual AAQC x 15

It should be noted that the cancer-based AAQC or corresponding POI standards may be derived based on a risk level of greater than one in a million. This happens when the air standards are not immediately achievable because of implementation issues, which may include high background concentrations, technical feasibility, significant economic impacts, or allowing a reasonable time frame for compliance. The Ministry is in the process of developing a risk management framework to resolve these potential implementation issues.

In the case of the risk assessment for the Rodney Street community, air monitoring data comes from several sources and locations. Local air sampling for nickel, lead, copper and total suspended particulates was obtained from the Ministry's sampling station at Davis Street and Fraser Street, which operated from 1992 to 1996, and air sampling done during the summer of 2000 near schoolyards in Port Colborne by Jacques Whitford Environmental Limited (JWEL, 2000a). The Ministry's sampling station was about 600m north of Rodney Street. Prevailing winds in the general Port Colborne area are from the west and southwest. These sectors account for about 45-50% of winds. The other sectors occur less and fairly evenly, about 5-15% each (Frank Dobroff, MOE, personal communication). While the Davis and Fraser location may be deemed slightly upwind of the Rodney Street community, inspection of the nickel concentration in soil maps in the Ministry's Phytotoxicology Soil Investigation Reports (MOE, 1999; MOE, 2000) indicate that it is located in an area where nickel levels in surface soils range up to 1,000 µg/g, and depending on wind direction would sample air particulates representative of the area just north of Rodney Street. The air monitoring performed at Port Colborne schools in the summer of 2000 (JWEL 2000a) was only collected for the portion of the year that dust levels would normally be higher and may not be representative of long term average levels in the community. However, in all cases where air monitoring data exists for arsenic, cobalt, copper, nickel, and TSP, the maximum and average air concentrations for each metal from the JWEL (2000a) air monitoring are less than or comparable with either the MOE or Environment Canada information.

Air concentrations of other metals not sampled extensively in Port Colborne (antimony, arsenic, cadmium, cobalt, lead) were taken from Environment Canada's National Air Pollution Surveillance (NAPS) air monitoring program for Ontario for 1995-1999 (Tom Dann, Environment Canada, personal communication). Environment Canada air monitoring data comes from nine sites spread across Ontario, six of which are in Hamilton, Toronto and Windsor. In general, the Environment Canada air monitoring data for the same chemicals sampled by MOE at Davis and Fraser (the maximum and annual average air concentrations) was lower. In the absence of more suitable air quality data for chemicals not sampled extensively in Port Colborne, Environment Canada air monitoring data was used.

Air monitoring data for beryllium is not available either from Environment Canada or MOE air monitoring programs. In order to estimate potential health effects from inhaling airborne beryllium in the Rodney Street community, it was assumed that the total suspended particulates (TSP) data from MOE monitoring at Davis and Fraser for 1992-1995 would have the same beryllium concentration as soil in the Rodney Street community.

As a check on the possible relationship between soil metal concentrations and metal levels in re-suspended dust, the same calculation using the highest average TSP concentration from MOE monitoring at Davis and Fraser for 1992-1995, and the highest surface soil metal concentration in soil in the Rodney Street community is shown in Table A3-3. In general, these artificial re-suspended soil as TSP calculations fall into a range overlapping the other air monitoring data since the artificial numbers range from near the highest annual average (antimony, cadmium, copper) to near the maximum air concentrations (arsenic, cobalt, lead and nickel) found in the MOE or Environment Canada air monitoring data. A summary of the metal levels in air, used in the current assessment is provided in Table A3-3.

**Table A3-3: Levels of Metals in Ambient Air in Port Colborne**

| | Metal Concentration in Air in Port Colborne (µg/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Short term maximum | 0.0115 | n/a | 0.0067 | 0.017 | 0.56 | 0.69 |
| Annual average (highest) | 0.0011 | 0.00012 | 0.0007 | 0.002 | 0.11 | 0.033 |
| Re-suspended soil calculation | 0.0012 | 0.00012 | 0.00026 | 0.012 | 0.057 | 0.55 |

To assess the potential health risks related to inhalation, the highest annual average air concentration from the MOE or Environment Canada air monitoring data was used. This is more appropriate to estimate long term inhalation exposure, and, inhalation RfC and unit risks are developed for life-time exposure not short term maximum air concentrations. Characterization of potential health risks from inhalation is discussed in Section 5.0 of the Human Health Risk

Assessment main report (Part B) (Risk Characterization).

In the Rodney Street community, inhaled metals will be associated with particulate matter and will not be present as free metal. Therefore, there is a potential for the inhaled particulate matter to be cleared from the lungs, through mucocilliary transport, and swallowed. Material cleared from the lungs in this fashion will add to the total daily ingestion of metal. The amount of particulate delivered to the stomach by this process is difficult to predict with any accuracy. Therefore, to provide conservative estimates of the amount of metal ingested as a result of the clearance of inhaled particles, it has been assumed that all inhaled metal is cleared from the lung and passed to the stomach. This approach will overestimate the contribution that inhalation exposures make to the total daily intakes of metals. The estimated inhalation intake of each metal for each receptor based on the highest annual average level (Table A3-3) is shown in Table A3-4. These values are calculated as shown in equation A3-2.

**Eq A3-2:**

$$Intake_{air} = Intake_{airout} + Intake_{airin}$$

$$Intake_{airout} = (Time_{outsum} * IR_{air} * Cair_{out}) + (Time_{outwin} * IR_{air} * Cair_{out})$$

$$Intake_{airin} = (Time_{insum} * IR_{air} * Cair_{in}) + (Time_{inwin} * IR_{air} * Cair_{in})$$

Where: $\text{Intake}_{air}$ = Intake from air µg/day
$\text{Intake}_{airout}$ = Intake from air while outdoors µg/day
$\text{Intake}_{airin}$ = Intake from air while indoors µg/day
$\text{IR}_{air}$ = Inhalation rate $m^3$/day
$\text{Cair}_{out}$ = Outdoor air concentration (measured) µg/$m^3$
$\text{Cair}_{in}$ = Indoor air concentration µg/$m^3$
(75% of outdoor air concentration based on Roberts et al. (1974))
$\text{Time}_{insum}$ = Fraction of time spent indoors during summer; see Appendix 6 unitless
$\text{Time}_{inwin}$ = Fraction of time spent indoors during winter; see Appendix 6 unitless
$\text{Time}_{outsum}$ = Fraction of time spent outdoors during summer; see Appendix 6 unitless
$\text{Time}_{outwin}$ = Fraction of time spent outdoors during winter; see Appendix 6 unitless

**Table A3-4: Estimated Metal Intakes from Air**

| Metal | Receptor | $C_{air}$ (µg/$m^3$) | $IR_{air}$ ($m^3$/day) | $\text{Intake}_{air}$ (µg/day) |
|---|---|---|---|---|
| Antimony | 0 - 6 months | 0.0011 | 2.1 | 0.0018 |
| | 7 mo - <5 years | 0.0011 | 9.3 | 0.008 |
| | 5 - <12 years | 0.0011 | 14.5 | 0.013 |
| | 12 - <20 years | 0.0011 | 15.8 | 0.014 |
| | 20 + years | 0.0011 | 15.8 | 0.014 |
| Beryllium | 0 - 6 months | 0.00012 | 2.1 | 0.00020 |
| | 7 mo - <5 years | 0.00012 | 9.3 | 0.0009 |
| | 5 - <12 years | 0.00012 | 14.5 | 0.0014 |
| | 12 - <20 years | 0.00012 | 15.8 | 0.0015 |
| | 20 + years | 0.00012 | 15.8 | 0.0015 |

| Metal | Receptor | C (μg/m$^3$) | IR (m$^3$/day) | Intake (μg/day) |
|---|---|---|---|---|
| Cadmium | 0 - 6 months | 0.0007 | 2.1 | 0.0011 |
| | 7 mo - <5 years | 0.0007 | 9.3 | 0.005 |
| | 5 - <12 years | 0.0007 | 14.5 | 0.008 |
| | 12 - <20 years | 0.0007 | 15.8 | 0.009 |
| | 20 + years | 0.0007 | 15.8 | 0.009 |
| Cobalt | 0 - 6 months | 0.002 | 2.1 | 0.0033 |
| | 7 mo - <5 years | 0.002 | 9.3 | 0.015 |
| | 5 - <12 years | 0.002 | 14.5 | 0.023 |
| | 12 - <20 years | 0.002 | 15.8 | 0.025 |
| | 20 + years | 0.002 | 15.8 | 0.025 |
| Copper | 0 - 6 months | 0.112 | 2.1 | 0.18 |
| | 7 mo - <5 years | 0.112 | 9.3 | 0.8 |
| | 5 - <12 years | 0.112 | 14.5 | 1.3 |
| | 12 - <20 years | 0.112 | 15.8 | 1.4 |
| | 20 + years | 0.112 | 15.8 | 1.4 |
| Nickel | 0 - 6 months | 0.033 | 2.1 | 0.05 |
| | 7 mo - <5 years | 0.033 | 9.3 | 0.24 |
| | 5 - <12 years | 0.033 | 14.5 | 0.37 |
| | 12 - <20 years | 0.033 | 15.8 | 0.41 |
| | 20 + years | 0.033 | 15.8 | 0.40 |

### A3-1.4 Intake of Metals from Backyard Garden Produce

Eating produce grown in backyards where metal levels are above typical levels, represents a potential exposure pathway if the metals present in the soil are taken up into the plant. The exposures received by people eating such produce depends upon the concentration of the metals in the fruits and vegetables and the amount of fruits and vegetables consumed from backyard gardens. The current assessment has assumed that backyard garden produce is consumed on a daily basis throughout the year. The amount of backyard garden fruits and vegetables consumed on an annually averaged daily basis is discussed in detail in Appendix 6.

As part of the ongoing work in Port Colborne, samples of backyard produce have been collected by the MOE and JWEL from Rodney and Mitchell Streets. The levels of individual metals in the various types of produce tested are provided in Appendix 1 of this report. For the purposes of this assessment, backyard garden produce has been divided into three general categories in order to ensure consistency with food consumption rates provided in Appendix 6;

| | |
|---|---|
| *root vegetables* | includes: beet root, carrot, onion and radish |
| *other vegetables* | includes: beet tops, celery, lettuce, peppers, rhubarb, squash, leeks and tomatoes |
| *fruits* | includes: pear, apple, cantaloupe, peach, plum, watermelon, and grapes |

For nickel, additional data sources such as those compiled from journal articles, MOE reports, and other relevant studies and reports have also been considered. Studies using forms of nickel with exceptionally high bioavailability to plants or forms of nickel more soluble ($NiCl_2$ or $NiSO_4$) than in the Rodney Street soils (predominantly NiO) were not considered. Studies investigating only low soil nickel concentrations were also not considered. Port Colborne data prior to 1984 were not considered since they would have been strongly influenced by atmospheric deposition of Inco emissions such that nickel concentrations in produce have resulted from atmospherically deposited nickel. The following table provides all data sources considered for this evaluation and the rationale for the selection of relevant data sets.

**Table A3-5: Data Sources Considered for Vegetation Uptake of Nickel**

| Data Source | Reason for Exclusion |
|---|---|
| MOE. 1977. Effect of Heavy Metal on the Growth of Lettuce, Celery, and Onion, Groetelaars Farm, Port Colborne. | atmospheric deposition |
| MOE. 1978a. Investigations of the Effects of Heavy Metals on Muck Farms East of International Nickel Company, Port Colborne, Ontario, 1976 - 1977. | atmospheric deposition |
| MOE. 1978b. Investigations of the Effects of Heavy Metals on Muck Farms East of International Nickel Company, Port Colborne, Ontario, 1976-1977. Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section. | atmospheric deposition |
| MOE. 1979. Phytotoxicology Complaint Investigation, J. Overholt, Port Colborne, 1979. | atmospheric deposition |
| OMAF. 1980. Report on Agronomic Problems Experienced by Three Growers Located Near Port Colborne. | atmospheric deposition |
| MOE. 1980a. Investigations of Agronomic Problems Associated with Metal Toxicity on Muck Farms in the Vicinity of Inco, Port Colborne, 1976-1979. | atmospheric deposition |
| MOE. 1980b. Phytotoxicology Complaint Investigation, J. Overholt, Port Colborne, 1980. | atmospheric deposition |

| Data Source | Reason for Exclusion |
|---|---|
| MOE. 1981. Effects of Heavy Metals and Root Knot Nematode on Celery Grown on Organic Soil in the Vicinity of International Nickel Company, Port Colborne, Ontario, 1980. | atmospheric deposition |
| MOE. 1983. Levels of Ni, Cu, and Co in Vegetable and Soil Samples Collected from Residential Gardens in the Vicinity of Inco Limited, Port Colborne. | atmospheric deposition |
| MOE. 1984a. Investigation of Alleged $SO_2$ Injury to Celery on Overholt Farm, Port Colborne, October 3, 1983. | atmospheric deposition |
| MOE. 1984b. Nickel Phytotoxicity on Celery and Lettuce Grown on Soil Contaminated by a Nickel Refinery. | atmospheric deposition |
| MOEE. 1994. Nickel Uptake into Vegetables Growing in Experimental Plots. Ecological Standards & Toxicology Section, MOEE, unpublished data. | low soil concentrations |
| Deloro Village Exposure Assessment and Health Risk Characterization for Arsenic and Other Metals, Cantox Environmental Inc., December, 1999. | low soil concentrations |
| JWEL 2001. 2001 Food Basket Collection. Unpublished data supplied by JWEL on October 4, 2001. | not excluded |
| JWEL 2000b. Garden soil data - Rodney Street area, sampled from the 18th-22nd of September, 2000. | not excluded |
| MOE. 2001. Garden soil and plant data from Rodney Street, Sampled from November 2000 to January 2001. | not excluded |
| Biró, B., I. Köves-Péchy, and I. Kádár. 1998. Toxicity of Some Field Applied Heavy Metal Salts to the Rhizobial and Fungal Microsymbionts of Alfalfa and Red Clover. Agrokémia és Talajtan 42:265-276. | $NiSO_4$ (soluble form of nickel) |
| Braillier, S., R.B. Harrison, C.L. Henry, and X. Dongsen. 1996. Liming effects on availability of Cd, Cu, Ni and Zn in a soil amended with sewage sludge 16 years previously. Water, Air and Soil Pollution 86:195-206. | low soil concentrations |
| Frank, R., K.I. Stonefield, P. Suda, and J.W. Potter. 1982. Impact of nickel contamination on the production of vegetables on an organic soil, Ontario, Canada, 1980-1981. Sci. Total Environ. 26:41-65. | atmospheric deposition |
| Guo, Y., R. Schulz, and H. Marschner. 1995. Genotypic differences in uptake and distribution of cadmium and nickel in plants. Agnew. Bot. 69:42-48. | $NiSO_4$ (soluble form of nickel) & low soil concentrations |
| L'Huillier, L., and S. Edighoffer. 1996. Extractability of nickel and its concentration in cultivated plants in Ni rich ultramafic soils of New Caledonia. Plant and Soil. 186:255-264. | Soil with exceptionally high nickel bioavailability |
| Maclean, A.J. and A.J. Dekker. 1978. Availability of zinc, copper and nickel to plants grown in sewage treated soils. Can. J. Soil Sci. 58:381-389. | $NiSO_4$ (soluble form of nickel) |
| Sajwan, K.S., W.H. Ornes, T.V. Youngblood, and A.K. Alva. 1996. Uptake of soil applied cadmium, nickel, and selenium by bush beans. Water, Air, Soil Pollut. 91:209-217. | $NiCl_2$ (soluble form of nickel) & low soil concentrations |

| Data Source | Reason for Exclusion |
|---|---|
| Sauerbeck, D. R., and A. Hein. 1991. The nickel uptake from different soils and its prediction by chemical extractions. Water, Air, Soil Pollut. 57-58: 861-871. | low soil concentrations |
| Traynor, M.F. and B.D. Knezek. 1973. Effects of nickel and cadmium contaminated soils on nutrient composition of corn plants. Proc. Annual Conf. on Trace Substances in the Environment 7:82-87. | $NiCl_2$ (soluble form of nickel) |
| Vergnano Gambi, O., R. Gabbrielli, and L. Pancaro. 1982. Nickel, chromium and cobalt in plants from Italian serpentine areas. Acta Oecologica Oecologica Plantarum 3(17): 291-306. | low soil concentrations |

Data sources were narrowed down to three relevant data sets (JWEL, 2000b, JWEL 2001 and MOE, 2001 data) that were reflective of current conditions. Laboratory analysis of vegetables typically report concentrations on a dry weight basis. This was the case for the all of the JWEL (2000b) and MOE (2001) and some of the JWEL (2001) data discussed above. Since vegetables are not typically consumed in a dry state, these concentrations were converted to a fresh (or wet) weight (as consumed). To convert dry weight to fresh weight, dry weight tissue concentrations were multiplied by the appropriate dry weight to wet weight conversion factor based on the typical moisture contents of vegetables. The USDA (1963), Baes et al., (1984) and US EPA (1997) have recommended dry weight to wet weight conversion factors for several fruits and vegetables collected as part of the JWEL (2000b), MOE (2001) and JWEL (2001) surveys (Table A3-7). Where plant specific factors were not available, the conversion factor was based on a similar plant type. The majority of the JWEL (2001) data was provided on a wet weight basis (conversion was not necessary for this data).

**Table A3-6: Dry Weight to Wet Weight Conversion Factors**

| Vegetables | Conversion Factor | Fruits | Conversion Factor |
|---|---|---|---|
| Beets | 0.13 | Apples | 0.15 |
| Broccoli | 0.093 | Cantaloupes | 0.10 |
| Cabbage | 0.0468 | Grapes | 0.19 |
| Carrots | 0.12 | Peaches | 0.11 |
| Celery | 0.059 | Pears | 0.17 |
| Leeks | 0.124 | Plums | 0.21 |
| Lettuce | 0.045 | Watermelons | 0.10 |
| Onions | 0.11 | | |
| Parsnips | 0.21 | | |
| Peppers | 0.066 | | |
| Radish/Horse Radish | 0.0516 | | |
| Rhubarb | 0.052 | | |
| Squash | 0.057 | | |
| Tomatoes | 0.065 | | |

A review of the available produce data indicated that the concentrations of metals in produce is not strongly affected by the levels of metals present in the soil and as such it was not possible to derive appropriate uptake factors for the Rodney Street community. As a result, upper bound produce concentrations measured in the area were assumed for all gardens in the assessment. With the exception of nickel, maximum values were selected due to limited data sets (see Appendix A1). For nickel, over 180 relevant plant samples were available and as a result it was considered more appropriate to select an upper bound plant concentration to represent all gardens in the assessment (Appendix A1 presents the data available at the time of this assessment). The 95th percentile concentration was selected based on the following rationale: (i) others have considered the 95th percentile of a non-normal distribution to be representative of an upper bound value (the data set appears to be log-normally distributed); (ii) the data set is highly skewed and maximum values would not be reflective of reasonable upper bound exposures; (iii) a typical diet would consist of a composite of the available produce types, while the maximum level is only reflective of a single plant type and garden location. No distinction was made for different produce types, rather the selected upper bound concentration was assumed to represent all plant types. These selected levels are reported in Table A3-7.

**Table A3-7: Metal Levels in Backyard Produce in Port Colborne**

| Vegetable | Metal Concentrations in Vegetables (μg/g) (Fresh Weight) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Root Vegetables | 0.021 | 0.007 | 0.063 | 0.048 | 1.92 | 2.44 |
| Other Vegetables | 0.021 | 0.007 | 0.063 | 0.048 | 1.92 | 2.44 |
| Fruits | 0.021 | 0.007 | 0.063 | 0.048 | 1.92 | 2.44 |

Daily intakes of metal from backyard produce are calculated as shown in equation A3-3. Estimates of daily metals intakes from backyard garden produce for all age groups are shown in Table A3-8.

**Eq A3-3:**

$$Intake_{veg} = \left(IR_{root} * C_{root}\right) + \left(IR_{other} * C_{other}\right)$$

| Where: | | | | |
|---|---|---|---|---|
| | $Intake_{veg}$ | = | Intake from backyard garden produce | μg/day |
| | $IR_x$ | = | Yearly averaged daily intake of backyard root or other vegetables (see Appendix 6) | g/day |
| | $C_x$ | = | Metal concentration in root/other vegetables on a wet weight basis | μg/g |

**Table A3-8: Estimated Metal Intakes from Backyard Vegetables**

| Metal | Receptor | Root Vegetables | | | Other Vegetables | | | Fruits | | | Total (μg/day) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $C_{root}$ (μg/g) | $IR_{root}$ (g/day) | $Intake_{veg}$ (μg/day) | $C_{root}$ (μg/g) | $IR_{other}$ (g/day) | $Intake_{veg}$ (μg/day) | $C_{root}$ (μg/g) | $IR_{fruit}$ (g/day) | $Intake_{veg}$ (μg/day) | |
| Antimony | 0 - 6 months | 0.021 | 6.05 | 0.127 | 0.021 | 5.25 | 0.11 | 0.021 | 3.96 | 0.08 | 0.32 |
| | 7 mo - <5 years | 0.021 | 7.65 | 0.161 | 0.021 | 4.88 | 0.10 | 0.021 | 6.81 | 0.14 | 0.41 |
| | 5 - <12 years | 0.021 | 11.7 | 0.25 | 0.021 | 7.14 | 0.15 | 0.021 | 7.80 | 0.16 | 0.56 |
| | 12 - <20 years | 0.021 | 16.5 | 0.35 | 0.021 | 8.75 | 0.18 | 0.021 | 7.51 | 0.16 | 0.69 |
| | 20 + years | 0.021 | 13.7 | 0.29 | 0.021 | 9.99 | 0.21 | 0.021 | 7.13 | 0.15 | 0.65 |

| Metal | Receptor | Root Vegetables | | | Other Vegetables | | | Fruits | | | Total (µg/day) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $C_{root}$ (µg/g) | $IR_{root}$ (g/day) | $Intake_{veg}$ (µg/day) | $C_{root}$ (µg/g) | $IR_{other}$ (g/day) | $Intake_{veg}$ (µg/day) | $C_{root}$ (µg/g) | $IR_{fruit}$ (g/day) | $Intake_{veg}$ (µg/day) | |
| Beryllium | 0 - 6 months | 0.007 | 6.05 | 0.04 | 0.0070 | 5.25 | 0.037 | 0.0070 | 3.96 | 0.028 | 0.11 |
| | 7 mo - <5 years | 0.007 | 7.65 | 0.05 | 0.0070 | 4.88 | 0.034 | 0.0070 | 6.81 | 0.048 | 0.14 |
| | 5 - <12 years | 0.007 | 11.7 | 0.08 | 0.0070 | 7.14 | 0.050 | 0.0070 | 7.80 | 0.055 | 0.19 |
| | 12 - <20 years | 0.007 | 16.5 | 0.12 | 0.0070 | 8.75 | 0.061 | 0.0070 | 7.51 | 0.053 | 0.23 |
| | 20 + years | 0.007 | 13.7 | 0.10 | 0.0070 | 9.99 | 0.070 | 0.0070 | 7.13 | 0.050 | 0.22 |
| Cadmium | 0 - 6 months | 0.063 | 6.05 | 0.38 | 0.063 | 5.25 | 0.33 | 0.063 | 3.96 | 0.25 | 0.96 |
| | 7 mo - <5 years | 0.063 | 7.65 | 0.48 | 0.063 | 4.88 | 0.31 | 0.063 | 6.81 | 0.43 | 1.22 |
| | 5 - <12 years | 0.063 | 11.7 | 0.74 | 0.063 | 7.14 | 0.45 | 0.063 | 7.80 | 0.49 | 1.7 |
| | 12 - <20 years | 0.063 | 16.5 | 1.0 | 0.063 | 8.75 | 0.55 | 0.063 | 7.51 | 0.47 | 2.1 |
| | 20 + years | 0.063 | 13.7 | 0.86 | 0.063 | 9.99 | 0.63 | 0.063 | 7.13 | 0.45 | 1.9 |
| Cobalt | 0 - 6 months | 0.048 | 6.05 | 0.29 | 0.048 | 5.25 | 0.25 | 0.048 | 3.96 | 0.19 | 0.73 |
| | 7 mo - <5 years | 0.048 | 7.65 | 0.37 | 0.048 | 4.88 | 0.23 | 0.048 | 6.81 | 0.33 | 0.9 |
| | 5 - <12 years | 0.048 | 11.7 | 0.56 | 0.048 | 7.14 | 0.34 | 0.048 | 7.80 | 0.37 | 1.3 |
| | 12 - <20 years | 0.048 | 16.5 | 0.8 | 0.048 | 8.75 | 0.42 | 0.048 | 7.51 | 0.36 | 1.6 |
| | 20 + years | 0.048 | 13.7 | 0.66 | 0.048 | 9.99 | 0.5 | 0.048 | 7.13 | 0.3 | 1.5 |
| Copper | 0 - 6 months | 1.92 | 6.05 | 12 | 1.92 | 5.25 | 10.1 | 1.92 | 3.96 | 7.6 | 29 |
| | 7 mo - <5 years | 1.92 | 7.65 | 15 | 1.92 | 4.88 | 9.4 | 1.92 | 6.81 | 13.1 | 37 |
| | 5 - <12 years | 1.92 | 11.7 | 22 | 1.92 | 7.14 | 14 | 1.92 | 7.80 | 15 | 51 |
| | 12 - <20 years | 1.92 | 16.5 | 32 | 1.92 | 8.75 | 17 | 1.92 | 7.51 | 14 | 63 |
| | 20 + years | 1.92 | 13.7 | 26 | 1.92 | 9.99 | 19 | 1.92 | 7.13 | 14 | 59 |
| Nickel | 0 - 6 months* | | | | | | | | | | |
| | 7 mo - <5 years | 2.44 | 7.65 | 19 | 2.44 | 4.88 | 12 | 2.44 | 6.81 | 17 | 47 |
| | 5 - <12 years | 2.44 | 11.7 | 29 | 2.44 | 7.14 | 17 | 2.44 | 7.80 | 19 | 65 |
| | 12 - <20 years | 2.44 | 16.5 | 40 | 2.44 | 8.75 | 21 | 2.44 | 7.51 | 18 | 80 |
| | 20 + years | 2.44 | 13.7 | 33 | 2.44 | 9.99 | 24 | 2.44 | 7.13 | 17 | 75 |

*While it is possible that the infant would consume some produce in the first six months of life, home garden produce was not considered since total diet estimates included produce and inclusion of home garden produce would over-estimate infant exposures

## A3-1.5 Intake of Metals from Soil/Dust

The metals of concern in the Rodney Street community area of Port Colborne are generally tightly bound to soil particles and are present in forms that either have limited solubility in water or are largely insoluble. However, the solubility of these metals increases under acidic conditions. When ingested, metals that are insoluble in water at neutral pH (6.0 - 8.0) can be solubilized and removed from soil particles in the acidic environment of the stomach. The metals released from the soil in the stomach become accessible for uptake by the gut. Ingested metals that remain bound to soil particles in the gut are not available for absorption and are excreted in the feces. The daily intake of metal from ingested soil is a function of the amount of soil ingested, the level of metal contained in the soil and the amount of metal released from the soil particles under the acidic conditions of the stomach. Similarly, metals are bound to indoor dusts in much the same way as soil, since the source of some of the indoor dust is actually soil from outdoors. While the physical characteristics of dusts may be significantly different than those of soil (eg., particle size and composition), current data does not allow for an adequate distinction between the exposures from these two media. As a result, the current assessment considers these as a combined media group. The estimated daily intake of metal from the ingestion of soil is calculated as shown in equation A3-4.

**Eq A3-4:**

$$Intake_{soil} = Intake_{soilout} + Intake_{soilin}$$

$$Intake_{soilout} = \left[\left(Csoil_{out} * Fract_{winter} * Fract_{out} * WF\right) + \left(Csoil_{out} * \left(1 - Fract_{winter}\right) * Fract_{out}\right)\right] * IR_{soil} * Bio_{soil}$$

$$Intake_{soilin} = \left[\left(Cdust_{in} * Fract_{winter} * \left(1 - Fract_{out}\right)\right) + \left(Cdust_{in} * \left(1 - Fract_{winter}\right) * \left(1 - Fract_{out}\right)\right)\right] * IR_{soil} * Bio_{soil}$$

| | | | | |
|---|---|---|---|---|
| Where: | $Intake_{soil}$ | = | Intake from soil/dust | µg/day |
| | $Intake_{soilout}$ | = | Intake from soil while outdoors | µg/day |
| | $Intake_{soilin}$ | = | Intake from dust while indoors | µg/day |
| | $IR_{soil}$ | = | Soil/dust ingestion rate | g/day |
| | $Bio_{soil}$ | = | Fraction of metal released from soil/dust in stomach | unitless |
| | $Csoil_{out}$ | = | Outdoor soil concentration (measured) | µg/g |
| | WF | = | 10% winter covering factor assumed* | |
| | $Cdust_{in}$ | = | Indoor dust concentration (0.39 indoor dust to outdoor soil concentration ratio; see Appendix 6) | µg/g |
| | $Fract_{out}$ | = | Fraction of daily soil ingestion rate allocated to outdoor exposure; see Appendix 6 | unitless |
| | $Fract_{winter}$ | = | Fraction of year that is considered winter; see Appendix 6 | unitless |

*A winter covering factor has been assumed for the Rodney Street community. The basis of this factor is the following: (i) between December and March, daily minimum temperatures average less than 0°C for Port Colborne (Environment Canada; Climate Normals) indicating that the ground is likely to remain frozen throughout these months reducing the accessibility of the soil for direct contact and movement of dust into homes; (ii) between December and March, daily maximum temperatures average less than 5°C for Port Colborne (Environment Canada; Climate Normals); due to these colder temperatures, it is likely that children will not be 'playing' in the dirt with exposed skin; most children will wear mittens or gloves throughout these winter months (iii) between December and March, most precipitation is in the form of snow, as a result, the ground will tend to be covered and unaccessible throughout this time period. On the basis of these factors, it has been assumed that contact with the soil will be approximately 1/10 for the four winter months as compared with other months of the year.

The soil ingestion rates and activity patterns for each of the receptor age groups are listed in Table 4-3 of the main report. The highest reported level of each metal in the soil from the Rodney Street community was used to estimate the daily ingestion of metal from soil. The $Bio_{soil}$ parameter is a measure of the amount of metal that is released from the soil under the acidic conditions of the stomach. This represents the amount of metal that is considered to be bio-accessible, or available to the gut for uptake, from the soil. The amount of each metal released from the soil in the stomach has been estimated using a simulated stomach acid leach test. The test methodology is discussed in detail in Appendix 5. The results of the stomach acid leach test for each metal are also provided in Appendix 5. For each metal, the maximum reported result was used to estimate the amount of metal that would be bio-accessible. This was used to estimate the effective daily intake for each metal from soil. The estimated daily intake of each metal from the soil is shown in Table A3-9.

**Table A3-9: Estimated Metal Intakes from Soil**

| Metal | Receptor | $C_{soil}$ (µg/g) | $IR_{soil}$ (g/day) | $Bio_{soil}$ | Total (µg/day) |
|---|---|---|---|---|---|
| Antimony | 0 - 6 months | 91.1 | 0.035 | 0.32 | 0.54 |
| | 7 mo - <5 years | 91.1 | 0.100 | 0.32 | 1.54 |
| | 5 - <12 years | 91.1 | 0.100 | 0.32 | 1.54 |
| | 12 - <20 years | 91.1 | 0.020 | 0.32 | 0.309 |
| | 20 + years | 91.1 | 0.020 | 0.32 | 0.309 |
| Beryllium | 0 - 6 months | 4.56 | 0.035 | 0.59 | 0.050 |
| | 7 mo - <5 years | 4.56 | 0.100 | 0.59 | 0.144 |
| | 5 - <12 years | 4.56 | 0.100 | 0.59 | 0.144 |
| | 12 - <20 years | 4.56 | 0.020 | 0.59 | 0.0287 |
| | 20 + years | 4.56 | 0.020 | 0.59 | 0.0287 |
| Cadmium | 0 - 6 months | 35.3 | 0.035 | 0.76 | 0.498 |
| | 7 mo - <5 years | 35.3 | 0.100 | 0.76 | 1.42 |
| | 5 - <12 years | 35.3 | 0.100 | 0.76 | 1.42 |
| | 12 - <20 years | 35.3 | 0.020 | 0.76 | 0.284 |
| | 20 + years | 35.3 | 0.020 | 0.76 | 0.284 |
| Cobalt | 0 - 6 months | 262 | 0.035 | 0.29 | 1.41 |
| | 7 mo - <5 years | 262 | 0.100 | 0.29 | 4.02 |
| | 5 - <12 years | 262 | 0.100 | 0.29 | 4.02 |
| | 12 - <20 years | 262 | 0.020 | 0.29 | 0.805 |
| | 20 + years | 262 | 0.020 | 0.29 | 0.805 |
| Copper | 0 - 6 months | 2720 | 0.035 | 0.43 | 20.7 |
| | 7 mo - <5 years | 2720 | 0.100 | 0.43 | 61.9 |
| | 5 - <12 years | 2720 | 0.100 | 0.43 | 61.9 |
| | 12 - <20 years | 2720 | 0.020 | 0.43 | 12.4 |
| | 20 + years | 2720 | 0.020 | 0.43 | 12.4 |
| Nickel | 0 - 6 months | 17000 | 0.035 | 0.19 | 59.9 |
| | 7 mo - <5 years | 17000 | 0.100 | 0.19 | 171 |
| | 5 - <12 years | 17000 | 0.100 | 0.19 | 171 |
| | 12 - <20 years | 17000 | 0.020 | 0.19 | 34.2 |
| | 20 + years | 17000 | 0.020 | 0.19 | 34.2 |

### A3-1.6 Intake of Metals Through Dermal Contact with Soil/Dust

Daily contact with metals through soil present on the skin represents a potential route of exposure. However, the insoluble nature of most metals in soil limits their bio-accessability for uptake into and through the skin. Where data is available, it shows that dermal uptake of metals is low (Paustenbach, 2000). The rate at which a metal is taken up into the outer layers of the skin is referred to as the *dermal uptake coefficient* (DUC). For the purposes of the current exposure assessment, the dermal uptake coefficients have been used to represent the amount of metal delivered to the skin surface from the soil that would be accessible for uptake. This is considered to be the *delivered dose* and has been considered to be equivalent to the dermal intake. A detailed discussion of the derivation of the DUC values for each of the metals is provided in Appendix 7. The delivered dose, is calculated as shown in Eq A3-5. These values have been used in conjunction with the estimates of intake from other sources to provide an estimate of the total daily dose for each age group for each metal (Table A3-10).

## Eq A3-5:

$$Intake_{dermal} = Intake_{dermout} + Intake_{dernin}$$

$$Intake_{dermout} = \left[\left(Csoil_{out} * Time_{outwin} * SA_{win} * WF\right) + \left(Csoil_{out} * Time_{outsum} * SA_{sum}\right)\right] * A_{soil} * EF * DUC_{soil}$$

$$Intake_{der\,min} = \left[\left(Cdust_{in} * Time_{inwin} * SA_{win}\right) + \left(Cdust_{in} * Time_{insum} * SA_{sum}\right)\right] * A_{soil} * EF * DUC_{soil}$$

Where: $Intake_{dermal}$ = Dermal intake from soil/dust µg/day
$Intake_{dermout}$ = Dermal intake from soil/dust while outdoors µg/day
$Intake_{dermin}$ = Dermal intake from dust while indoors µg/day
$A_{soil}$ = Soil adhesion to skin mg/cm$^2$/event
EF = Exposure Frequency (1 event/day) event/day
$DUC_{soil}$ = Dermal uptake coefficient unitless
$Csoil_{out}$ = Outdoor summer soil concentration (measured) µg/g
WF = 10% winter covering factor assumed (see above)
$Cdust_{in}$ = Indoor summer dust concentration (0.39 indoor dust to outdoor soil concentration ratio; see Appendix 6) µg/g
$SA_{win}$ = Exposed surface area during winter months; see Appendix 6 m2
$SA_{sum}$ = Exposed surface area during summer months; see Appendix 6 m2
$Time_{insum}$ = Fraction of time spent indoors during summer; see Appendix 6 unitless
$Time_{inwin}$ = Fraction of time spent indoors during winter; see Appendix 6 unitless
$Time_{outsum}$ = Fraction of time spent outdoors during summer; see Appendix 6 unitless
$Time_{outwin}$ = Fraction of time spent outdoors during winter; see Appendix 6 unitless

### Table A3-10: Estimated Metal Intakes from Dermal Contact with Soil

| Metal | Receptor | $C_{soil}$ (µg/g) | $A_{soil}$ (mg/cm$^2$/event) | $DUC_{soil}$ | $Intake_{dermal}$ (µg/day) |
|---|---|---|---|---|---|
| Antimony | 0 - 6 months | 91.1 | 0.2 | 0.010 | 0.098 |
| | 7 mo - <5 years | 91.1 | 0.2 | 0.010 | 0.167 |
| | 5 - <12 years | 91.1 | 0.2 | 0.010 | 0.276 |
| | 12 - <20 years | 91.1 | 0.07 | 0.010 | 0.146 |
| | 20 + years | 91.1 | 0.07 | 0.010 | 0.156 |
| Beryllium | 0 - 6 months | 4.56 | 0.2 | 0.010 | 0.00495 |
| | 7 mo - <5 years | 4.56 | 0.2 | 0.010 | 0.00845 |
| | 5 - <12 years | 4.56 | 0.2 | 0.010 | 0.0139 |
| | 12 - <20 years | 4.56 | 0.07 | 0.010 | 0.00739 |
| | 20 + years | 4.56 | 0.07 | 0.010 | 0.00789 |
| Cadmium | 0 - 6 months | 35.3 | 0.2 | 0.010 | 0.038 |
| | 7 mo - <5 years | 35.3 | 0.2 | 0.010 | 0.0649 |
| | 5 - <12 years | 35.3 | 0.2 | 0.010 | 0.107 |
| | 12 - <20 years | 35.3 | 0.07 | 0.010 | 0.0568 |
| | 20 + years | 35.3 | 0.07 | 0.010 | 0.0606 |
| Cobalt | 0 - 6 months | 262 | 0.2 | 0.004 | 0.0113 |
| | 7 mo - <5 years | 262 | 0.2 | 0.004 | 0.0192 |
| | 5 - <12 years | 262 | 0.2 | 0.004 | 0.0317 |
| | 12 - <20 years | 262 | 0.07 | 0.004 | 0.0168 |
| | 20 + years | 262 | 0.07 | 0.004 | 0.018 |

| Metal | Receptor | $C_{soil}$ (µg/g) | $A_{soil}$ (mg/cm$^2$/event) | $DUC_{soil}$ | $Intake_{dermal}$ (µg/day) |
|---|---|---|---|---|---|
| Copper | 0 - 6 months | 2720 | 0.2 | 0.010 | 2.93 |
| | 7 mo - <5 years | 2720 | 0.2 | 0.010 | 4.99 |
| | 5 - <12 years | 2720 | 0.2 | 0.010 | 8.23 |
| | 12 - <20 years | 2720 | 0.07 | 0.010 | 4.37 |
| | 20 + years | 2720 | 0.07 | 0.010 | 4.66 |
| Nickel | 0 - 6 months | 17000 | 0.2 | 0.00038 | 0.695 |
| | 7 mo - <5 years | 17000 | 0.2 | 0.00038 | 1.19 |
| | 5 - <12 years | 17000 | 0.2 | 0.00038 | 1.96 |
| | 12 - <20 years | 17000 | 0.07 | 0.00038 | 1.04 |
| | 20 + years | 17000 | 0.07 | 0.00038 | 1.11 |

## A3-2 Summary

For each receptor age group daily metal intakes have been estimated for each of the pathways of concern. For each metal, intakes from all exposure pathways must be combined for each receptor in order to estimate the total daily dose received by each receptor age group. This summation of exposures is presented in Section 4.4 of the Human Health Risk Assessment main report (Part B).

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# Appendix 4

# Estimating Daily Intakes of Metals from Supermarket Food

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## A4-1 Estimating Metal Intakes from Supermarket Food

Estimates of the dietary intakes of metals from supermarket food by the general Canadian population are limited. Daily dietary intake estimates for cadmium, cobalt, copper and nickel have been published by CEPA (Health Canada and Environment Canada), CCME and others (see Table A4-1). Information on dietary intakes for all age groups is not available for all metals. For example, information on dietary intakes of antimony and beryllium are limited to single estimates of daily intake by the general population (FSA, 1997;Vaessen and Szteke, 2000).

## A4-2 Estimating Dietary Intakes of Metals for All Age Groups

The lack of dietary intakes for all age groups used in this assessment required that intake estimates be derived from available information. The shaded areas in Table A4-1 indicate where such derivations have been necessary. Cadmium intake rates were recalculated from CEPA (1994a and 1994b) values using current receptor characteristic values to obtain units in μg/day.

**Table A4-1: Estimated Total Daily Intakes of Metals from Supermarket Food**

| Receptor | Daily Intakes of Metals from Supermarket Food (μg/day) | | | | | |
|---|---|---|---|---|---|---|
| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
| Infant | 1.3 | 4.8 | 5.08 | 4.18 | 518 | 109.2 (72.2-146.2)* |
| Toddler | 2.3 | 8.6 | 10.6 | 7.0 | 822 | 190 |
| Child | 3.5 | 13.2 | 16.8 | 10.0 | 1230 | 251 |
| Teen | 4.0 | 15.0 | 17.3 | 12.0 | 1520 | 313 |
| Adult | 3.4 | 12.7 | 14.8 | 11.0 | 1430 | 307 |
| Reference | FSA, 1997 | Vaessen & Szteke, 2000 | CEPA, 1994a | Dabeka & McKenzie, 1995 | CCME, 1997 | Dabeka, 1989; Dabeka & McKenzie, 1995 |

Shaded cells represent calculated values (see text for explanations)
*see table A4-4

CEPA and CCME provide daily dietary intake estimates for cadmium, and copper for all age groups. The age groups examined by Dabeka and McKenzie (1995) differ slightly from those used by CEPA and CCME. Dabeka and McKenzie (1995) do not report intakes for children age 0 - 1 year, and their toddler age group includes children aged 1 - 4 years rather than the 7 months to less than 5 years used by CEPA and CCME. Dabeka and McKenzie (1995), CEPA and CCME use the same age groupings for children (5 - 11 years), teens (12 - 19 years) and adults (20+ years). For the purposes of this assessment the intake estimates provided by Dabeka and McKenzie (1995) for cobalt for toddlers, have been applied to the toddler (7 months to less than 5 years) used in this assessment. The nickel and cobalt intakes for infants, shown in Table A4-1 have been estimated based on the intakes reported for toddlers. The ratios were determined by averaging the ratios of infant and toddler intakes for other metals as shown in equation A4-1.

**Eq A4-1:**

$$C_I = \left[ \frac{\left(\frac{I_{As}}{T_{As}}\right) + \left(\frac{I_{Cd}}{T_{Cd}}\right) + \left(\frac{I_{Cu}}{T_{Cu}}\right) + \left(\frac{I_{Ni}}{T_{Ni}}\right)}{4} \right] = 0598$$

Where:
$C_I$ = Correction factor for infant intake
$I_x$ = Infant intake for arsenic, cadmium, copper, and nickel
$T_x$ = Toddler intake for arsenic, cadmium, copper, and nickel

## A4-3 Additional Information on Dietary Intakes for Antimony, Beryllium and Nickel

Dietary intake information for antimony and beryllium is limited to a single, general population estimate for each (FSA, 1997; Vaessen and Szteke, 2000). In order to develop likely total daily intakes from supermarket foods for all age groups of concern in this assessment, the single values have been used as a basis for estimating intakes in all age groups. A ratio process similar to the one outlined in Equation A4-1 was used. The estimated daily intakes of antimony and beryllium are 4 µg/day (FSA, 1997) and 15 µg/day (Vaessen and Szteke, 2000), respectively. A review of intake data for the other metals shows that the highest daily intakes of metals generally occurs in the "teen" age group for all metals considered (See Table A4-1). Therefore, the values reported for antimony and beryllium were assigned to this age group. Ratios for metal intakes between the teen age group and the other age groups were developed for arsenic, cadmium, cobalt and lead. The average of these values for each of the age groups was used to generate the intake estimates for antimony and beryllium for each of the age groups. The derivation of the ratios is shown in Table A4-2.

**Table A4-2: Dietary Intake Ratios for Different Age Groups for Arsenic, Cadmium, Cobalt and Lead**

| Receptor | Daily Intakes of Metals from Supermarket Food (µg/day) | | | | | | | | Averaging Ratio |
|---|---|---|---|---|---|---|---|---|---|
| | Arsenic | | Cadmium | | Cobalt | | Lead | | |
| | Intake | Ratio | Intake | Ratio | Intake | Ratio | Intake | Ratio | |
| Infant | 19.70 | 0.28 | 5.08 | 0.29 | 4.18 | 0.35 | 8.97 | 0.37 | 0.32 |
| Toddler | 33.00 | 0.46 | 10.60 | 0.61 | 7.00 | 0.58 | 15.00 | 0.63 | 0.57 |
| Child | 62.50 | 0.87 | 16.80 | 0.97 | 10.00 | 0.83 | 20.00 | 0.83 | 0.88 |
| Teen | 71.60 | 1.00 | 17.30 | 1.00 | 12.00 | 1.00 | 24.00 | 1.00 | 1.00 |
| Adult | 42.40 | 0.59 | 14.80 | 0.86 | 10.50 | 0.88 | 25.70 | 1.07 | 0.85 |

Dietary intake information for arsenic was taken from Yost et al., (1998). Information on lead in the diet comes from Dabeka and MacKenzie (1995).

Because nickel and copper can be added during food processing operations, it was felt that the levels of these metals would not provide a true reflection of trace metal levels in foods. Therefore nickel and copper were not considered in the development of the ratios used to estimate the daily intakes of the trace metals antimony and beryllium.

### A4-3.1 Antimony

There is very limited data on dietary intakes of antimony in general/supermarket food. ATSDR (1990) estimated that the antimony concentration in the diet of a typical adult male was 9.3 µg/kg dry weight. The WHO used the information cited by the ATSDR to develop an estimate of the daily intake of antimony from food of 18 µg/day (WHO, 1996). Two studies that post date the work cited by ATSDR and the WHO have also examined dietary intakes of antimony (FSA, 1997 and Miahara et al., 1998). Miahara et al., (1998), examined antimony intakes in preschool children and the elderly in Brazil. Estimates of dietary intake ranged between 1.1 µg/day and 2.3 µg/day. The Food Standards Agency in Great Britain estimated dietary intakes of antimony in the British population. The study found a mean daily intake of 3 µg/day with a 97.5 percentile estimate of 4 µg/day. The study further noted that these values are approximately ten fold lower than the previous estimate of 29 µg/day that was based on a 1976 survey. The difference was attributed to a significant lowering of analytical detection limits between the time of the two studies (FSA, 1997). Although the WHO suggested a daily intake of 18 µg/day in 1996, this value was based on estimates developed before changes in analytical techniques allowed for better estimates of antimony levels in foods. As a result, the WHO value is likely to overestimate daily dietary intakes of antimony. For the purposes of this assessment, the upper estimate of 4 µg/day suggested by the FSA has been used to estimate dietary intakes of antimony for the residents of Rodney Street in Port Colborne. The upper FSA estimate (4 µg/day) was assumed to be a lifetime daily intake for a typical Rodney Street teen and was prorated to average estimates of supermarket food intake for other age classes as shown in Table A4-3.

### A4-3.2 Beryllium

Information on the dietary exposure to beryllium is limited. Recently, a review of the worldwide literature on the occurrence of beryllium in food and drinking water and estimates of daily dietary exposure was sponsored by the Food Chemistry Commission of the International Union for Pure and Applied Chemistry (IUPAC) (Vaessen and Szteke, 2000). Beryllium levels in food were found to range from <1 to approximately 20 µg/kg fresh weight. In the US, the average beryllium concentration in drinking water is 0.2 µg/L. Estimates of beryllium intake from food consumption for the UK and the US ranged from 12 to 15 µg/day, however, these food intakes were considered to be rough estimates. The 15 µg/day estimate was assumed to be a lifetime daily intake for a typical Rodney Street teen and was prorated to average estimates of supermarket food intake for other age classes as shown in Table A4-3.

**Table A4-3: Sample Calculation of Estimated Dietary Intakes for Each Age Class Using Averaging Ratios**

| Receptor | Averaging Ratio | Daily Intakes of Metals from Supermarket Food (µg/day) | | | |
|---|---|---|---|---|---|
| | | Antimony | | Beryllium | |
| | | Reported | Calculated | Reported | Calculated |
| Infant | 0.323 | - | 1.3 | - | 4.8 |
| Toddler | 0.571 | - | 2.3 | - | 8.6 |
| Child | 0.878 | - | 3.5 | - | 13.2 |
| Teen | 1.00 | 4.0 | 4.0 | 15.0 | 15.0 |
| Adult | 0.848 | - | 3.4 | - | 12.7 |

### A4-3.3 Nickel

Interpreting information from dietary intake studies requires assessing a whole range of information from levels of nickel in specific food items to how this information is integrated into overall population intakes by age class and averages and percentiles for each age class. Some agencies report just average intakes for the adult population, others indicate upper ranges of intake, as well, and sometimes just a range of intakes is reported. Consequently, the full range of intakes reported by various agencies is tabulated in Table A4-4.

Several studies have attempted to estimate the daily intake of nickel from supermarket or processed food in the Canadian and North American populations. Based on the US Food and Drug Administration's Total Diet Study of 1984, the mean nickel consumption of infants and young children was 69 to 90 µg/day (Pennington and Jones, 1987). Average daily dietary intake of nickel in the US has been reported as 168 µg/day (Myron et al., 1978; cited in ATSDR, 1997). A more recent review of dietary intake has included nickel intakes from dietary supplements and estimates that adults consume 76 to 105 µg/day of nickel from diet and supplements (IOM, 2001). The US dietary intake data formatted to match the Canadian age class groups is shown in Table A4-4.

A 1984 market basket survey of dietary nickel intake in England determined an intake of 154-166 µg/day (Smart and Sherlock, 1987). More recently, the results of the 1997 UK Total Diet Study were published (Ysart et al., 2000). The average dietary exposure for UK adults was 120 µg/day and the 97.5th percentile was 210 µg/day, similar to their 1994 survey. This information was prorated to Canadian age class intervals using the averaging ratios in Table A4-3 and is shown in Table A4-4.

CEPA, provides estimates of daily nickel intakes from food for the general Canadian population (CEPA, 1994b). These estimates are based on a survey of nickel concentrations in various foods conducted by National Health and Welfare, 1992 and estimates of age specific food intakes derived from a Nutrition Canada, Environmental Health Directorate survey (CEPA, 1994c). More detailed information on dietary intakes of nickel by Canadians was reported in Dabeka and McKenzie (1995). The Canadian dietary intake of nickel for all ages, male and female, is 286 µg/day (Dabeka and McKenzie (1995)). It is not indicated whether the Canadian dietary intakes are averages or some upper range, however, inspection of the tables of nickel levels in various food categories indicates that the reported Canadian dietary intakes are average values.

Inspection of Table A4-4 shows that Canadian dietary nickel intakes are higher than US and UK estimates. Dabeka and McKenzie (1995) comment on this situation and indicate that the highest nickel intakes were for meat and poultry (about 40%), bakery goods and cereals (about 19%), soups (about 15%) and vegetables (about 11%). These data are felt to provide the best representation of likely nickel intakes from food for the Canadian population as a whole. Therefore these values have been used to represent the intake of nickel from non-home grown food sources for the residents of Rodney Street (Table A4-1).

The available research indicates that the use of stainless-steel cookware does not appreciably add to the amount of nickel or chromium ingested. A study by Accominotti et al., (1994) found that the levels of metals released during cooking were still less than the tolerable daily intake (TDI) recommended by the World Health Organization. This was supported by other studies which found that certain acidic fruits could leach metals. A study by Kuligowski and Halperin (1992) found that stainless is readily attacked by organic acids at cooking temperatures and mildly acidic pH. As a result, iron, chromium, and nickel did leach from the material into the food being prepared. Nickel was a major corrosion product from stainless steel utensils and the authors recommend that nickel-sensitive patients switch to utensils made from a material other than stainless steel. Studies have indicated that the vast majority of the nickel available to the food would be leached out of the cookware on the first use. However, this situation did not recur in subsequent usage, even after the cookware had been cleaned via abrasion (Flint and Packirisamy, 1997). The study by Dabeka and McKenzie (1995) did indicate that stainless steel cooking utensils (eg., oven pan and roasting pan) appear to contribute to the higher levels of nickel in cooked steak, ground beef, port, lamb, and poultry. This may provide some rationale as to why the intake concentrations reported by Dabeka and his colleagues were higher than those presented in our jurisdictions.

**Table A4-4: Estimated Daily Dietary Intake of Nickel for Various Countries**

| [illegible] Source | Daily Intake 0 - 6 months (µg/day) | Daily Intake [illegible] | Daily Intake [illegible] | Daily Intake 12-19 year [illegible] | Daily Intake Adult [illegible] |
|---|---|---|---|---|---|
| CEPA, 1994b | 154 | 208 | 270 | 325 | 308 |
| Dabeka, 1989; Dabeka and McKenzie, 1995 | 109.2 (72.2-146.2)* | 190 | 251 | 313 | 307 |
| US FDA Total Dietary Study (95th %ile)(IOM, 2001) | 9(37) (reported) | 81(153) (recalculated) | 107(199) (recalculated) | 125(250) (recalculated) | 119(233) (recalculated) |
| UK Total Dietary Study 1997(97.5th %ile) (Ysart et al., 2000) | 39(68) (calculated) | 68(120) (calculated) | 105(184) (reported) | 120(210) (reported) | 102(178) (calculated) |

* the CEPA and Dabeka (1989) infant diet is based on dietary surveys taken in the 1970s. A comparison of the infants exposures under the following scenarios is provided:

- Diet A - assumes that the infant only consumes breast milk for six months.
- Diet B - assumes that the infant only consumes formula for six months.
- Diet C - assumes that the infant consumes breast milk or formula only for the first three months, and this diet is then supplemented by vegetables, cereal and bread, and, fruit and fruit juices.

Diet A - Recent studies of nickel in human milk using the ICP-MS analytical method indicate low levels in European mothers. Biego et al., (1998) did not detect nickel in seventeen French breast milk samples at a reported detection limit of 2.9 µg/L. Krachler et al., (2000) analysed milk samples from 27 Austrian mothers and reported a median value of 0.79 µg/L (range - detection limit (0.13 µg/L) to 6.35 µg/L). In a recent Canadian study, milk from 43 mothers living in Newfoundland was analysed during the first 12 weeks of breast feeding (Friel et al., 1998). Median values for nickel ranged from 0 to 28 µg/L. If an infant consumes 850 mL breast milk per day (Emmett et al., 2000), nickel intakes resulting from Diet A could range from 0.67 µg/day to 23.8 µg/day.

Diet B - Dabeka (1989) reported milk-based formulas as having half the nickel content of soy based formulas. For the zero - six month age group, reported nickel intakes from formula range from 35.7 µg/day (evaporated milk) to 74.7 µg/day (soy-based formula).

Diet C - The combination diet (Diet C) suggested above uses Nutrition Canada's values for vegetable, cereal and fruit intakes for this age group (33 g, 34.4 g and 75.7 g /day, respectively). Using the overall nickel intake for each of these food groups based on Dabeka and McKenzie (1995) and the Nutrition Canada food intake factors, this results in a nickel intake estimate of 143 µg/day. Diet A and three months of vegetable, cereal and fruit intakes suggests overall intakes of 72.2 µg/day to 95.3 µg/day over the first six months. Similarly, Diet B and three months of vegetable, cereal and fruit intakes suggests overall intakes of 107.2 µg/day to 146.2 µg/day over this period. The mid point of this range (72.2 to 146.2 µg/day) is 109.2 µg/day.

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# Appendix 5

## Bioaccessibility and Bioavailability of Metals Following Ingestion of RSC Soils / Dusts and Other Environmental Media (Food, Drinking Water)

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## A5-0 Bioavailability and Bioaccessibility

In broad terms, the bioavailability of a compound can be defined as the fraction of an administered dose that reaches the central (blood) compartment, whether through gastrointestinal tract, skin, or lungs (NEPI, 2000). This form of bioavailability is typically referred to as "absolute bioavailability". However, when evaluating potential differences in the bioavailability of a compound that is encountered *via* different routes of exposure, it is also useful to understand the "relative bioavailability" of the compound. Relative bioavailability refers to comparative bioavailabilities of different forms of a compound (eg., metal species) or for different exposure media containing the chemical (eg., bioavailability of a chemical bound to soil *versus* its bioavailability in water) (NEPI, 2000). Relative bioavailability is typically expressed as a relative absorption factor (RAF), which provides the absorbed fraction of the compound from a particular exposure medium relative to the fraction absorbed from the dosing vehicle used in the toxicity study for that particular compound (NEPI, 2000).

In risk assessment, oral exposures are typically stated in terms of the external dose or intake, instead of in terms of absorbed dose or uptake. The distinction between intake and uptake is also an important one. Intake is typically defined as the process by which an agent crosses the outer exposure surface of a human or animal without passing an absorption barrier (eg., through ingestion or inhalation), while uptake is the process by which an agent crosses an absorption barrier into human or animal (IPCS, 2000).

Consideration of relative bioavailability allows the intake to be adjusted to reflect variations in bioavailability of a chemical in a different exposure media. The term "bioaccessible" will be used to indicate the fraction of the chemical intake that is directly available for uptake. As the current assessment is primarily driven by the consideration of dietary nickel consumption, the focus of this discussion will be on the use of relative bioavailability and bioaccessibility in estimating oral exposures to nickel in different exposure media.

Exposure assessment of the oral route of exposure considers ingestion of food, water and soil. The default relative bioavailability factor for ingestion intakes is 1.0 in different exposure media. Use of this default value assumes that the bioavailability of the chemical being evaluated in any exposure medium will always be the same as its bioavailibilty using a different exposure medium than the one being assessed. More recently, as our understanding of how chemicals behave as they pass through the digestive tract is applied to exposure assessment methodologies, variations in relative bioavailability and the bioaccessible fraction of ingested chemicals is being taken into account. The US EPA has indicated that when the oral exposure limit is based on studies where not all the chemical in the diet administered to the test animals was absorbed, some adjustment of the oral exposure estimate is permitted. Other agencies also are adjusting oral intakes estimates for differences in relative bioavailability. What is happening is that while the bioavailability factor default is still 1.0, the bioaccessible fraction is being adjusted to account for what is known about the behavior of specific chemicals in the gut.

In the case of many metals, pH is an important variable controlling the bioaccessible fraction of ingested metals. As ingested materials containing these metals pass through the digestive tract, the low (acid) pH of the stomach can increase the bioacccessible fraction considerably while passing through this part of the digestive tract. After the stomach, the digestive tract reverts to higher pH (neutral to alkaline) and the bioaccessible fraction of metals may change. Investigators have tried to simulate conditions in the digestive tract experimentally using *in vitro* tests. These involve various degrees of complexity from simple acid solutions to controlled pH regimes and the addition of digestive enzymes, bile, food and other components of digestion. It should be kept in mind that the pH of the stomach can vary from pH 1 to pH 1.5 under fasting conditions up to pH 4 during active digestion of food. The transit time of ingested materials is related to gastric emptying and can vary from less than an hour for liquids to over three hours for solid food. Whether the food is carbohydrate, protein or fat can also control transit time. Consequently, *in vitro* stomach acid tests using pH 1 to pH 1.5 represent fasting stomach conditions and are highly conservative. The validity of some *in vitro* models has been assessed by comparison with *in vivo* bioavailability assays in test animals.

For nickel, our knowledge of oral bioavailability is based on soluble nickel salts administered to test animals and human subjects in the diet or in water (see discussion in sections A5-1 and A5-2). There is little information on oral exposure to insoluble nickel compounds. These studies indicate that soluble nickel salts administered under fasting conditions (stomach pH about 1) results in up to 30% bioavailability (uptake). Under non-fasting conditions and in the presence of food (stomach pH about 4), bioavailability (uptake) of soluble nickel salts is much lower (2% to 5%). Limited information indicates that the bioavailability of insoluble nickel compounds is < 1%. What these studies suggest is that the bioaccessible fraction of soluble nickel in the stomach increased at the low fasting stomach pH. In non-fasting conditions, the bioaccessible fraction decreased with increasing pH and the amount of nickel absorbed decreased proportionately. Based on the data of Griffin et al., (1990) and Ishimatsu et al., (1995), it is assumed that soil bound insoluble nickel would be less accessible than soluble forms.

The bioavailability of metallic or other insoluble forms of metals ingested in a soil matrix may be considerably lower than that of the soluble forms of the metals. Bioaccessibility refers to the fraction of the metal in the ingested soil which dissolves in the gastro-intestinal (GI) tract and is available for absorption. Bioaccessibility can be measured *in vitro* using simulated GI tract fluids. This is a nonequilibrium process given the limited time for passage through the GI tract which may not allow the metal to completely dissolve. Bioaccessibility of a metal is affected by a large range of soil properties including particle size, whether the metal is part of the crystalline structure of a mineral in the soil or is adsorbed onto the surface of soil components, and soil pH.

## A5-1 Bioavailability of Nickel Ingested in Water or Food

There are several studies of nickel administered to human volunteers where urinary excretion of nickel was measured and absorption of the administered dose was calculated. A recent review summarized most of these studies (Diamond et al., 1998). The following table (Table A5-1) updates that review. It should be noted that all estimates of % bioavailability of nickel which are primarily based on cumulative urinary excretion of nickel were calculated using simplified pharmacokinetic models or the cumulative excretion of nickel as a percentage of the ingested dose over three, four or five days.

The studies not described by Diamond et al., (1998) address orally administered isotopes of nickel (Templeton et al., 1994b; Patriarca et al., 1997; Nielsen et al., 1999). Templeton et al., (1994b) administered $^{61}$Ni orally in water to a human volunteer after an overnight fast. Urinary excretion of $^{61}$Ni demonstrated absorption of 30% of the administered dose. Pairs of human subjects were administered $^{62}$Ni in water (Patriarca et al., 1997); urinary and fecal excretion of $^{62}$Ni was followed for five days. Gastrointestinal absorption of $^{62}$Ni was estimated as the difference between ingested nickel and nickel excreted in urine and the feces. The absorbed dose was 33.1± 4.9%. Nielsen et al., (1999) performed two studies to examine the influence of fasting and food intake on the absorption and retention of nickel added to drinking water. In the first study, volunteers drank nickel dissolved in water either four hours or 1.5 hours before or during a scrambled egg breakfast, or 0.5 to one hour after the breakfast. The results show that bioavailability is lowest when nickel is co-administered with food, intermediate when food is taken within about an hour before or after the food and highest (approaching the high bioavailability shown by the fasting stomach) at four hours after eating.

All of these bioavailability studies involve ingestion of soluble nickel either in drinking water or mixed into food. Inspection of Table A5-1 shows fairly clearly that gastrointestinal absorption of soluble nickel in drinking water is maximal at 23% to 33% under fasting conditions (Cronin et al., 1980; Nielsen et al., 1999; Patriarca et al., 1997; Sunderman et al., 1989; Templeton et al., 1994b). Absorption of nickel is much lower in the presence of food (Christensen and Lagesson, 1981; Gawkrodger et al., 1986; Horak and Sunderman, 1973; McNeely et al., 1972; Menne et al., 1978; Nielsen et al., 1999; Spruit and Bongaarts, 1977; Sunderman et al., 1989). It is not clear whether the lowered absorption of nickel in the presence of food is due to nickel binding to food components or pH changes in the stomach associated with the presence of food. Patterns of peristalsis and gastric emptying into the intestines during ingestion may influence nickel absorption (Nielsen et al., 1999). No differences in nickel absorption related to gender or nickel sensitivity were found (Menne et al., 1978; Nielsen et al., 1999; Patriarca et al., 1997).

## A5-2 Oral Bioavailability of Nickel in Animals

Studies in mice, rats and dogs indicate that 1–10% of nickel, given as nickel, nickel sulphate, or nickel chloride in the diet or by gavage, is rapidly absorbed by the gastrointestinal tract (Ambrose et al., 1976; Ho and Furst 1973; Nielsen et al., 1993; Phatak and Patwardhan, 1952; Severa et al., 1995; Tedeschi and Sunderman 1957).

Absorption by the gastrointestinal tract depends on the solubility of the nickel compound. In a study in which rats were treated with a single gavage dose of a nickel compound (10 mg nickel) in a 5% starch saline solution, the absorption was found to be directly correlated with the solubility of the compound (Ishimatsu et al., 1995). The percentages of the dose absorbed were 0.01% for green nickel oxide, 0.09% for metallic nickel, 0.04% for black nickel oxide, 0.47% for nickel subsulphide, 11.12% for nickel sulphate, 9.8% for nickel chloride, and 33.8% for nickel nitrate. Absorption was higher for the more-soluble nickel compounds. Unabsorbed nickel is excreted in the feces.

$^{57}NiCl_2$ was administered either orally by gastric intubation or by intraperitoneal injection to *ad libitum* fed mice in doses equivalent to the average human daily dietary nickel intake (Nielsen et al., 1993). Whole body retention was measured by whole body counting of the radiation emitted by $^{57}Ni$. The intestinal absorption was estimated to be 1.7% to 10% after 20 to 50 hours.

Wistar strain rats were given 100 mg Ni/L (as nickel sulphate) in drinking water for six months (Severa et al., 1995). The urinary excretion of the orally administered nickel was estimated to be only 2%.

## A5-3 Bioavailability of Nickel Ingested in Soil

The oral bioavailability of nickel in soil is not well characterized. Currently, there are no published reports on the human bioavailability of nickel in soil. Griffin et al., (1990) compared the oral bioavailability of nickel chloride, a soluble salt, administered to rats either as an aqueous slurry with sandy loam or clay loam soil or in water. Nickel bioavailability was estimated from levels of nickel in the blood. The soil bound nickel had a reduced bioavailability relative to nickel chloride in water. The relative bioavailabilities of nickel in the sandy and clay loam slurries were 63% and 34%, respectively. The mean absolute bioavailabilities were 3% and 1.5% for the sandy and clay loam slurries, respectively. These absolute bioavailabilities are similar to those reported for nickel administered in animal diets.

## A5-4 Bioavailability and Bioaccessibility of Other Metals in Soil

Recent papers discussing the oral bioavailability of metals in soil as assessed by *in vitro* and *in vivo* techniques focus on arsenic and lead because of their large historic database (Ellickson et al., 2001; Hamel et al., 1998; Ruby et al., 1999). For both lead and arsenic, the bioavailability in soil has been shown to be reduced when compared to the bioavailability of soluble forms, ie., the relative bioavailability is less than the default value of 1.0. *In vivo* and *in vitro* studies have yielded similar results (Ruby et al., 1999).

## Table A5-1: Summary of Studies to Determine Bioavailability

| Study | n | Exposure medium | Duration | Fasting Status | % Bioavailability |
|---|---|---|---|---|---|
| Sunderman et al., 1989 | 88 | water<br>breakfast | acute<br>acute | fasted<br>fasted | 29.3<br>1.8 |
| Cronin et al., 1980 | 5 | gelatin capsule + 100 mL of water | acute | fasted | 12 - 32 |
| Christensen and Lagesson, 1981 | 8 | capsule | acute | w/meal | 5.7 |
| Gawkrodger et al., 1986 | 3 | capsule | acute | w/meal | 2.7, 2.8 |
| Menne et al., 1978 | 6 | capsule | acute | not fasted | 2.2 (women) |
| Menne et al., 1978 | 7 | capsule | acute | not fasted | 1.7 (men) |
| Spruit and Bongaarts, 1977 | 1 | solution | acute | not fasted | 0.8 |
| Horak and Sunderman, 1973 | 10 - 50 | food | chronic | not fasted | 1 |
| McNeely et al., 1972 | 1920 | food + water<br>food | chronic<br>chronic | not fasted<br>not fasted | 1.6<br>1.2 |
| Templeton et al., 1994a | 1 | 1 L water | acute | fasted | 30 |
| Patriarca et al., 1997 | 4 | capsules + water | acute | fasted | 33.1 (men and women) |
| Nielsen et al., 1999 | 1 | eggs 4.5 hours prior to Ni in 250 mL water | acute | fasted | 23.2 (men) |
| Nielsen et al., 1999 | 1 | eggs 1.5 hours prior to Ni in 250 mL water | acute | fasted | 7.1 (men) |
| Nielsen et al., 1999 | 1 | Ni in 250 mL water and eggs 0.5 or 1hour later | acute | fasted | 12.8 (men)<br>16.7 (men) |
| Nielsen et al., 1999 | 1 | Ni in 250 mL water and eggs together | acute | fasted | 3.4 (men)<br>2.3 (men) |
| Nielsen et al., 1999 | 20<br>20 | Ni in 250 mL water and eggs 4 hours later | acute<br>acute | fasted<br>fasted | 10.8 (1.8 - 29.5) (women)<br>11.3 (4 - 25.1) (women) |

## A5-5 *In vitro* Bioaccessibility Testing

*In vitro* methods for assessing oral bioavailability of heavy metals found in impacted soils and subsequently in exposure assessments of the human digestive system have been under active development for the past decade. Establishment of validated models for extraction of metals in digestive fluids to provide a tool for determining the metal exposure from any soil has been the focus of a number of groups (US Naval Facilities Engineering Command, 2000, Solubility/Bioavailability Research Consortium (Ruby et al, 1999), NEPI, 2000). Imitation biological fluids of the digestive tract can be prepared chemically, and their extraction capabilities examined to provide a measure of the maximum amount of the metal that can be made accessible in the gastrointestinal tract (bioaccessible) and which may cross the digestive tract membranes and be absorbed into the tissues. The artificial fluids evaluated in various studies of sequential extraction are 1) saliva, 2) gastric juice, and 3) duodenal fluid, which represent the major portions of the gastrointestinal tract involved in metal uptake by the body.

Ingested metals are transported by saliva to the stomach where the low pH enhances the dissolution of many metals. The first region of the small intestine, the duodenum, is the primary site of absorption of most metals, however, the conditions in the mouth and stomach may be important preconditions to uptake in this portion of the intestine. Enzymes in the prepared bio-fluids, the soil type chosen, and the soil matrix appear to also play a role in extraction capacity. Accurate simulation of the human digestive system includes consideration of fluid volumes, pH, additional digestive components (enzymes, salts, etc.), peristaltic behaviour (fasting vs. presence and type of food) and residence time.

Saliva is 99.5% water and contains sodium, potassium, chloride as the dominant ions. The main digestive enzymes are ptyalin (salivary amylase) secreted by the salivary glands. Lingual glands secrete a lipase. Saliva also contains mucin, a glycoprotein which lubricates the food. The optimal pH for ptyalin is pH 6.7. The normal flow rate of saliva ranges from 0.25 mL/min in the un-stimulated state up to 1 mL/min following stimulation by chewing. Consequently, over a one hour period the maximal production of saliva would be about 60 mL. The role of saliva in absorbing metals in the mouth does not appear to have been studied widely but since the pH of saliva is close to neutral, it is not expected to facilitate metal dissolution from soil.

Gastric secretion is stimulated by the presence of food in the stomach. Gastric acid contains 0.2% to 0.5% HCl (approx. 0.17 N HCl). The lowest pH is 0.87, but the resting human stomach is pH 1 to pH 1.5. Gastric fluid is mainly water with mucin, inorganic salts, pepsin (activated by HCl), rennin and gastric lipases. The stomach can hold two to three L, and produces up to 2.5 L of gastric fluids daily (ICRP, 1984, Ganong, 1989).

The small intestine is the largest part of the gastrointestinal tract and is composed of the duodenum which is about one foot long, jejunum (five - eight feet long), and ileum (16 - 20 feet long). The duodenum is the major portion of the small intestine where enzyme secretion takes place. The small intestine secretes sucrase, maltase, and lactase. It also secretes peptidase, and lipase. The duodenum receives bile from the liver and gallbladder. Lipase, amylase, trypsin, chymotrypsin and sodium bicarbonate to neutralize the acid chyme from the stomach, are received from the pancreas. Epithelial cells in the small intestine secrete several litres/day of a neutral fluid. Brunner's glands in the duodenum secrete mucus. Almost 90% of the daily fluid intake is absorbed in the small intestine.

All together food can remain in the small intestine between three - ten hours normally. Depending on what is in the stomach (water, solid food or both), gastric emptying into the duodenum can occur within 75 minutes to 3.5 hours (up to five hours) (ICRP, 1984, Ganong, 1989).

MOE used two methods to assess the bioaccessibility of metals of concern in Rodney Street community soils. Initially MOE used fasting stomach simulation tests based on 24 hour extractions, which are described in section A5-4.1. In addition, to validate the MOE bioaccessibility tests, and to account for metal bioaccessibility in other parts of the gastrointestinal tract, Rodney Street community soils samples were also sent out for testing using the Standard Operating Protocol developed by the Solubility / Bioavailability Research Consortium (Ruby et al., 1999). This protocol has been validated by comparison to animal studies for lead, but not for nickel. The results of the bioaccessiblity testing by the external laboratory are reported in section A5-4.2.

### A5-5.1 Simulated Stomach Acid Leachate Tests

MOE adapted the traditional Leachate Extraction Procedure (formerly described in Reg. 347), which is based on the Toxicity Characteristic Leaching Procedure, Method 1311 that appears in the United States Environmental Protection Agency Publication SW-846 entitled "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods", as amended from time to time and available online at http://www.epa.gov/epaoswer/hazwaste/test/main.htm) to simulate leaching of metals from soil under the acidic conditions found in the stomach. This method was originally designed to investigate the leaching behaviour of various hazardous chemicals in municipal, industrial and hazardous wastes.

Soil samples were analysed for bioaccessibility utilizing this adapted leaching method to simulate stomach digestion conditions. In this method bioaccessibility is estimated by comparing the amount of total metal extracted by routine ICP analysis with the amount of metal extracted from the soil samples using the simulated stomach acid digestion. The MOE Leachate Extraction Procedure was modified as follows:

- The 0.5 N acetic acid was replaced with 0.17 N HCL;
- 20 g dry weight soil sample used instead of 50 g;
- 400 ml acid used instead of 800 ml acid;
- Initial pH adjusted to pH 1 instead of pH 5.

This approach has been used to assess the amount of metal that would be released into the stomach from soil samples in other MOE community exposure studies.

Ten soil samples from the Rodney Street community, containing very high levels of nickel were selected for simulated stomach acid leach testing. For each soil sample, 20g of dried, sieved material (355 µm mesh size) was added to 400 ml of 0.17 N HCl (pH 1.0). The samples were agitated for 24 hours on a rotary extractor. The mixture was then filtered through a 4.5 micron filter and the filtrate was analyzed for metals and hydrides. For each sample, the percentage leached was calculated by dividing the mass of the metal in the leachate by the mass in the original soil sample and then multiplying the ratio by 100. The results of the analyses are shown in Tables A5-2 through A5-7. The maximum reported leached value was used to represent the amount of each metal that would be released from the soil in the stomach and would be available to contribute to actual exposures.

It is recognized that the use of a 24 hour digestion period, which is longer than the typical residency times for food in the stomach, will overestimate the amount of metal that will be released and available. However, it was believed that as a precautionary measure, that the potential overestimation of exposures was justified.

The Simulated Stomach Acid Leachate Test results displayed below (Tables A5-2 to A5-7) are the same laboratory data used in the March 2001 report. However, the data have been re-calculated to reflect the mass of metal extracted as a percentage of the mass of metal in the soil sample. Beryllium and cadmium levels in leachate were below detection limits.

**Table A5-2: Simulated Stomach Acid Leachate Test: Antimony**

| Level in Soil (ppm)[1] | Mass in 20 g (µg) | Amount Leached (ppm)[1] | Mass in Leachate (µg) | % Leached by Mass |
|---|---|---|---|---|
| 2.5 | 49.1 | 0.004 | 1.6 | 3.3 |
| 1.8 | 36.4 | 0.0035 | 1.4 | 3.9 |
| 2.1 | 41.9 | 0.0033 | 1.3 | 3.2 |
| 2.3 | 46.7 | 0.0033 | 1.3 | 2.8 |
| 2.8 | 56.5 | 0.0036 | 1.4 | 2.6 |
| 2.5 | 50.5 | 0.003 | 1.2 | 2.4 |
| 2.2 | 44.2 | 0.0033 | 1.3 | 3.0 |
| 2.0 | 40.2 | 0.0026 | 1.0 | 2.6 |
| 2.4 | 48.3 | 0.0025 | 1.0 | 2.1 |
| 2.1 | 41.0 | 0.0023 | 0.9 | 2.2 |
| **Averaged Values** | | | | |
| 2.3 | 45.5 | 0.00314 | 1.3 | 2.8 |
| **Minimum % Leached** | | | | 2.1 |
| **Maximum % Leached** | | | | 3.9 |

1: ppm is equivalent to µg/g in soil and µg/ml in leachate.

### Table A5-3: Simulated Stomach Acid Leachate Test: Arsenic

| Level in Soil (ppm)[1] | Mass in 20 g (µg) | Amount Leached (ppm)[1] | Mass in Leachate (µg) | % Leached by Mass |
|---|---|---|---|---|
| 52.0 | 1040 | 0.7 | 281.6 | 27.1 |
| 39.1 | 782 | 0.6 | 222.4 | 28.4 |
| 45.0 | 900 | 0.6 | 230.4 | 25.6 |
| 50.2 | 1004 | 0.7 | 275.6 | 27.5 |
| 63.1 | 1262 | 0.4 | 158.4 | 12.6 |
| 44.8 | 896 | 0.4 | 154.4 | 17.2 |
| 43.1 | 862 | 0.4 | 172.0 | 20.0 |
| 42.2 | 844 | 0.5 | 210.4 | 24.9 |
| 62.3 | 1246 | 0.5 | 217.6 | 17.5 |
| 37.6 | 752 | 0.5 | 205.6 | 27.3 |
| **Averaged Values** | | | | |
| 47.9 | 958.8 | 0.5 | 212.8 | 22.8 |
| **Minimum % Leached** | | | | 12.6 |
| **Maximum % Leached** | | | | 28.4 |

1: ppm is equivalent to µg/g in soil and µg/ml in leachate.

### Table A5-4: Simulated Stomach Acid Leachate Test: Cobalt

| Level in Soil (ppm)[1] | Mass in 20g (µg) | Amount Leached (ppm)[1] | Mass in Leachate (µg) | % Leached by Mass |
|---|---|---|---|---|
| 200 | 4000 | 2.0 | 784 | 19.6 |
| 180 | 3600 | 1.7 | 664 | 18.4 |
| 130 | 2600 | 1.2 | 468 | 18.0 |
| 140 | 2800 | 1.2 | 492 | 17.6 |
| 210 | 4200 | 2.4 | 940 | 22.4 |
| 160 | 3200 | 1.7 | 684 | 21.4 |
| 220 | 4400 | 1.7 | 676 | 15.4 |
| 150 | 3000 | 1.9 | 740 | 24.7 |
| 230 | 4600 | 1.4 | 576 | 12.5 |
| 120 | 2400 | 1.3 | 516 | 21.5 |
| **Averaged Values** | | | | |
| 174 | 3480 | 1.6 | 654 | 19.2 |
| **Minimum % Leached** | | | | 12.5 |
| **Maximum % Leached** | | | | 24.7 |

1: ppm is equivalent to µg/g in soil and µg/ml in leachate.

### Table A5-5: Simulated Stomach Acid Leachate Test: Copper

| Level in Soil (ppm)[1] | Mass in 20g (μg) | Amount Leached (ppm)[1] | Mass in Leachate (μg) | % Leached by Mass |
|---|---|---|---|---|
| 990 | 19800 | 17.2 | 6880 | 34.8 |
| 770 | 15400 | 17.1 | 6840 | 44.4 |
| 1000 | 20000 | 19.1 | 7640 | 38.2 |
| 780 | 15600 | 14.2 | 5680 | 36.4 |
| 1000 | 20000 | 15.9 | 6360 | 31.8 |
| 840 | 16800 | 14.7 | 5880 | 35.0 |
| 1000 | 20000 | 20.5 | 8200 | 41.0 |
| 980 | 19600 | 20.7 | 8280 | 42.2 |
| 970 | 19400 | 16.1 | 6440 | 33.2 |
| 640 | 12800 | 14.0 | 5600 | 43.8 |
| **Averaged Values** | | | | |
| 897 | 17940 | 17.0 | 6780 | 38.1 |
| **Minimum % Leached** | | | | 31.8 |
| **Maximum % Leached** | | | | 44.4 |

1: ppm is equivalent to μg/g in soil and μg/ml in leachate.

### Table A5-6: Simulated Stomach Acid Leachate Test: Lead

| Level in Soil (ppm)[1] | Mass in 20g (μg) | Amount Leached (ppm)[1] | Mass in Leachate (μg) | % Leached by Mass |
|---|---|---|---|---|
| 400 | 8000 | 15.6 | 6240 | 78.0 |
| 480 | 9600 | 21.1 | 8440 | 87.9 |
| 350 | 7000 | 12.8 | 5120 | 73.1 |
| 310 | 6200 | 11.1 | 4440 | 71.6 |
| 400 | 8000 | 13.3 | 5320 | 66.5 |
| 370 | 7400 | 14.4 | 5760 | 77.8 |
| 300 | 6000 | 9.17 | 3668 | 61.1 |
| 350 | 7000 | 11.4 | 4560 | 65.1 |
| 360 | 7200 | 15.4 | 6160 | 85.6 |
| 290 | 5800 | 13.1 | 5240 | 90.3 |
| **Averaged Values** | | | | |
| 361 | 7220 | 13.7 | 5495 | 75.7 |
| **Minimum % Leached** | | | | 61.1 |
| **Maximum % Leached** | | | | 90.3 |

1: ppm is equivalent to μg/g in soil and μg/ml in leachate.

**Table A5-7: Simulated Stomach Acid Leachate Test: Nickel**

| Level in Soil (ppm)[1] | Mass in 20g (µg) | Amount Leached (ppm)[1] | Mass in Leachate (µg) | % Leached by Mass |
|---|---|---|---|---|
| 8800 | 176000 | 86.2 | 34480 | 19.6 |
| 9200 | 184000 | 107 | 42800 | 23.3 |
| 11000 | 220000 | 93 | 37200 | 16.9 |
| 11000 | 220000 | 87.9 | 35160 | 16.0 |
| 12000 | 240000 | 88.5 | 35400 | 14.8 |
| 13000 | 260000 | 96.9 | 38760 | 14.9 |
| 14000 | 280000 | 127 | 50800 | 18.1 |
| 14000 | 280000 | 115 | 46000 | 16.4 |
| 16000 | 320000 | 104 | 41600 | 13.0 |
| 17000 | 340000 | 99.9 | 39960 | 11.8 |
| **Average** | | | | |
| 12600 | 252000 | 100.5 | 40216 | 16.5 |
| **Minimum % Leached** | | | | 11.8 |
| **Maximum % Leached** | | | | 23.3 |

1: ppm is equivalent to µg/g in soil and µg/ml in leachate.

### A5-5.2 External Bioaccessibility Studies

### A5-5.2.1 Methods

The following sections describe the manner in which the soil samples were prepared for analysis, the methods by which the bioaccessibility analyses were performed, and the results of these analyses.

Sample preparation included some preparation by the MOE Phytotoxicology Laboratory (described below). Further sample preparation and bioaccessibility extractions were performed in Exponent's laboratory in Boulder, Colorado (Exponent, 2001). Analyses for total metals concentrations for the eight metals of interest in the sample substrates and extraction fluids were conducted by Columbia Analytical Services, Inc. (CAS) in Kelso, Washington.

### A5-5.2.2 Sample Preparation and Analysis

Twenty samples were received at Exponent's Boulder laboratory in two separate shipments in May, 2001. The first shipment consisted of ten samples. Prior to receipt by Exponent, these samples had been dried, ground, and sieved to <350 µm, and each sample had been labeled with a three or four digit sample number. Exponent assigned six digit sample numbers; "SLO" was prefixed to the three digit sample numbers, and "SL" was prefixed to the four digit sample numbers. The dry samples were then sieved to <250 µm. These samples are referred to as "ground soil" in the tables.

The second shipment also consisted of ten samples. The soil samples in this shipment were "bulk" samples which had not been ground and sieved to <350 µm. Each sample had been similarly labeled with a three or four digit sample number. Again, Exponent assigned six digit sample numbers; "CSO" was prefixed to the three digit sample numbers, and "CS" was prefixed to the four digit sample numbers. The samples were then dried in the oven at 100°C for 24 hours, after which they were sieved to <250 µm. These samples are termed "sieved fine soil" in the tables.

The <250 µm soil size fraction was used for bioaccessibility testing, because it is believed to represent the fraction of soil that is most likely to adhere to human hands and become ingested during hand-to-mouth activity (Maddaloni et al., 1998). A one gram aliquot of each substrate was collected and subjected to the *in vitro* extraction procedure (described below). The rest of the sample was used for analysis of total metals concentrations for the eight metals of interest. As a quality control measure, an additional aliquot of one soil sample (sample number CS3740) was submitted as a triplicate for total metals analysis.

### A5-5.2.3 Bioaccessibility Testing

The sieved soil samples (<250 µm size fraction) were subjected to bioaccessibility testing according to the Standard Operating Procedure (SOP) developed by the Solubility/ Bioavailability Research Consortium (SBRC). This protocol is provided below *(in italics)*. The testing included extraction and analysis of one sample in triplicate (sample number SLO 415).

Deviations from the SBRC method with regard to sample preparation and analysis included the following:

- Analyses were conducted for antimony, beryllium, cadmium, cobalt, copper, and nickel, in addition to the analyses for arsenic and lead as specified in the SOP.

- The bioaccessibility test was modified to include a simulation of the small intestinal environment (ie., a second phase, at neutral pH, was added to the extraction procedure). This was done to evaluate whether an extraction procedure that simulates the environment of the small intestine would influence the bioaccessibility of metals from the sample substrates (eg., by affecting either the metal solubility or the integrity of the soil matrix that contains the metals). This was accomplished by adding the following steps at the end of the standard SBRC extraction procedure:

1. At the end of the 1 hour extraction, a 5mL sample of the extraction fluid was collected and preserved with nitric acid for analysis (as in the methods described in the SOP).

2. The extraction fluid in each bottle was then titrated to pH 7.0 ± 0.2 with NaOH (50% w/w) (this required approximately 20 drops of NaOH solution).

3. Once the extraction fluid had been neutralized, 175 mg of bile salts and 50 mg of pancreatin were added to each extraction bottle, and the bottles were returned to the extractor for an additional four hrs of extraction time.

4. At the end of the small-intestinal-phase extraction, a 10mL sample of the extraction fluid was collected from each bottle and filtered for analysis.

5. Matrix interference required that the arsenic analyses be conducted by graphite furnace atomic absorption (GFAA) rather than the inductively coupled plasma (ICP) method as specified in the SOP .

All of the extracts produced from the bioaccessibility testing were shipped to CAS for analysis of total concentrations of antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, and nickel.

### *Solubility/Bioavailability Research Consortium Standard Operating Procedure*

### *In vitro Method for Determination of Lead and Arsenic Bioaccessibility*

### *Procedure*

***Sample Preparation*** *- All soil/material samples should be prepared for testing by oven drying (<40 ℃) to reduce volatilization of any volatile metals and sieving to <250 μm. The <250-μm size fraction is used because this particle size is representative of that which adheres to children's hands. Sub-samples for testing in this procedure should be obtained using a sample splitter.*

### *Apparatus and Materials*

***Equipment*** *- The main piece of equipment required for this procedure consists of a Toxicity Characteristic Leaching Procedure (TCLP) extractor motor that has been modified to drive a flywheel. This flywheel in turn drives a Plexiglass block situated inside a temperature controlled water bath. The Plexiglass block contains ten 5cm holes with stainless steel screw clamps, each of which is designed to hold a 125mL wide mouth high density polyethylene (HDPE) bottle. The water bath must be filled such that the extraction bottles are immersed. Temperature in the water bath is maintained at 37±2 ℃ using an immersion circulator heater (for example, Fisher Scientific Model 730). Additional equipment for this method includes typical laboratory supplies and reagents, as described in the following sections.*

*The 125mL HDPE bottles must have an air tight screw cap seal (for example, Fisher Scientific 125mL wide mouth HDPE Cat. No. 02-893-5C), and care must be taken to ensure that the bottles do not leak during the extraction procedure.*

***Standards and Reagents*** *- The leaching procedure for this method uses a buffered extraction fluid at a pH of 1.5. The extraction fluid is prepared as described below.*

*The extraction fluid should be prepared using ASTM Type II deionized (DI) water. To 1.9 L of DI water, add 60.06 g glycine (free base, Sigma Ultra or equivalent). Place the mixture in a water bath at 37 °C until the extraction fluid reaches 37 °C. Standardize the pH meter using temperature compensation at 37 °C or buffers maintained at 37 °C in the water bath. Add concentrated hydrochloric acid (12.1 N, Trace Metal grade) until the solution pH reaches a value of 1.50 ±0.05 (approximately 120 mL). Bring the solution to a final volume of 2 L (0.4 M glycine).*

*Cleanliness of all reagents and equipment used to prepare and/or store the extraction fluid is essential. All glassware and equipment used to prepare standards and reagents must be properly cleaned, acid washed, and finally, rinsed with DI water prior to use. All reagents must be free of lead and arsenic, and the final fluid should be tested to confirm that lead and arsenic concentrations are less than 25 and 5 μg/L, respectively.*

***Leaching Procedure** - Measure 100 ±0.5 mL of the extraction fluid, using a graduated cylinder, and transfer to a 125mL wide mouth HDPE bottle. Add 1.00 ±0.05 g of test substrate (<250 μm) to the bottle, ensuring that static electricity does not cause soil particles to adhere to the lip or outside threads of the bottle. If necessary, use an antistatic brush to eliminate static electricity prior to adding the soil. Record the volume of solution and mass of soil added to the bottle on the extraction test checklist. Hand tighten each bottle top, and shake/invert to ensure that no leakage occurs, and that no soil is caked on the bottom of the bottle.*

*Place the bottle into the modified TCLP extractor, making sure each bottle is secure and the lid(s) are tightly fastened. Fill the extractor with 125mL bottles containing test materials or Quality Control samples.*

*The temperature of the water bath must be 37±2 °C. Record the temperature of the water bath at the beginning and end of each extraction batch on the appropriate extraction test checklist sheet.*

*Rotate the extractor end over end at 30±2 rpm for 1 hour. Record start time of rotation.*

*When extraction (rotation) is complete, immediately remove bottles, wipe them dry, and place them upright on the bench top.*

*Draw extract directly from reaction vessel into a disposable 20ml syringe with a Luer-Lok attachment. Attach a 0.45-μm cellulose acetate disk filter (25 mm diameter) to the syringe, and filter the extract into a clean 15mL polypropylene centrifuge tube or other appropriate sample vial for analysis. Store filtered sample(s) in a refrigerator at 4 °C until they are analyzed.*

*Record the time that the extract is filtered (ie., extraction is stopped). If the total elapsed time is greater than1 hour 30 minutes, the test must be repeated.*

*Measure and record the pH of fluid remaining in the extraction bottle. If the fluid pH is not* *within ±0.5 pH units of the starting pH, the test must be discarded and the sample re-analyzed as follows.*

*If the pH has dropped by 0.5 or more pH units, the test will be re-run in an identical fashion. If the second test also results in a decrease in pH of greater than 0.5 s.u., the pH will be recorded, and the extract filtered for analysis. If the pH has increased by 0.5 or more units, the test must be repeated, but the extractor must be stopped at specific intervals and the pH manually adjusted down to pH 1.5 with dropwise addition of HCl (adjustments at 5, 10, 15 and 30 minutes into the extraction, and upon final removal from the water bath [60 minutes]). Samples with rising pH values must be run in a separate extraction, and must not be combined with samples being extracted by the standard method (continuous extraction).*

*Extracts are to be analyzed for lead and arsenic concentration using analytical procedures taken from the US EPA publication, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846 (current revisions). Inductively coupled plasma (ICP) analysis, method 6010B (December 1996 revision) will be the method of choice. This method should be adequate for determination of lead concentrations in sample extracts, at a project required detection limit (PRDL) of 100 μg/L. The PRDL of 20 μg/L for arsenic may be too low for ICP analysis for some samples. For extracts that have arsenic concentrations less than five times the PRDL (eg., <100 μg/L arsenic), analysis by ICP-hydride generation (method 7061A, July 1992 revision) or ICP-MS (method 6020, September 1994 revision) will be required.*

***Calculation of the Bioaccessibility Value** - A split of each solid material (<250 μm) that has been subjected to this extraction procedure should be analyzed for total lead and/or arsenic concentration using analytical procedures taken from the US EPA publication, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846 (current revisions). The solid material should be acid digested according to method 3050A (July 1992 revision) or method 3051 (microwave-assisted digestion, September 1994 revision), and the digestate analyzed for lead and/or arsenic concentration by ICP analysis (method 6010B). For samples that have arsenic concentrations below ICP detection limits, analysis by ICP-hydride generation (method 7061A, July 1992 revision) or ICP-MS (method 6020, September 1994 revision) will be required.*

*The bioaccessibility of lead or arsenic is calculated in the following manner:*

$$\text{Bioaccessibility value} = \frac{(\text{Concentration in in vitro extract, mg/L})(0.1\text{L})}{(\text{Concentration in solid, mg/kg})(0.001\text{ kg})} \times 100$$

***Chain-of-Custody/Good Laboratory Practices** - All laboratories that use this SOP should receive test materials with chain-of-custody documentation. When materials are received, each laboratory will maintain and record custody of samples at all times. All laboratories that perform this procedure should follow good laboratory practices as defined in 40 CFR Part 792 (US EPA, 1999) to the extent practical and possible.*

***Data Handling and Verification*** *- All sample and fluid preparation calculations and operations should be recorded in bound and numbered laboratory notebooks, and on extraction test checklist sheets. Each page must be dated and initialed by the person who performs any operations. Extraction and filtration times must be recorded, along with pH measurements, adjustments, and buffer preparation. Copies of the extraction test checklist sheets should accompany the data package.*

### *Quality Control Procedures*

***Elements of Quality Assurance and Quality Control (QA/QC)*** *- A standard method for the in vitro extraction of soils/solid materials, and the calculation of an associated bioaccessibility value, are specified above. Associated QC procedures to ensure production of high quality data are as follows:*

- *Reagent blank—Extraction fluid analyzed once per batch.*
- *Bottle blank—Extraction fluid only run through the complete extraction procedure at a frequency of no less than 1 per 20 samples or one per extraction batch, whichever is more frequent.*
- *Blank spikes—Extraction fluid spiked at 10 mg/L lead and/or 1 mg/L arsenic and run through the extraction procedure at a frequency of no less than every 20 samples or one per extraction batch, whichever is more frequent. Blank spikes should be prepared using traceable 1,000 mg/L lead and arsenic standards in 2 percent nitric acid.*
- *Duplicate—duplicate extractions are required at a frequency of 1 for every 10 samples. At least one duplicate must be performed on each day that extractions are conducted.*
- *Standard Reference Material (SRM)—National Institute of Standards and Technology (NIST) material 2711 (Montana Soil) should be used as a laboratory control sample (LCS).*

*Control limits for these QC samples are delineated in Table A5-8, and in the following discussion.*

**Table A5-8: Summary of QC Samples, Frequency of Analysis, and Control Limits**

| *QC Sample* | *Minimum Frequency of Analysis* | *Control Limits* |
|---|---|---|
| *Reagent Blank* | *Once per batch (min. 5%)* | *<25 µg/L lead*<br>*<5 µg/L arsenic* |
| *Bottle Blank* | *Once per batch (min. 5%)* | *<50 µg/L lead*<br>*<10 µg/L arsenic* |
| *Blank Spike* | *Once per batch (min. 5%)* | *85–115% recovery* |
| *Duplicate* | *10%* | *±20% RPD* |
| *SRM (NIST 2711)* | *2%* | *9.22 ±1.50 mg/L Pb*<br>*0.59 ±0.09 mg/L As* |

***QA/QC Procedures*** *- Specific laboratory procedures and QC steps are described in the analytical methods and should be followed when using this SOP.*

***Laboratory Control Sample (LCS)*** *- The NIST SRM 2711 should be used as a laboratory control sample for the in vitro extraction procedure. Analysis of 18 blind splits of NIST SRM 2711 (105 mg/kg arsenic and 1,162 mg/kg lead) in four independent laboratories resulted in arithmetic standard deviations of 1.50 mg/L lead and 0.09 mg/L arsenic. This SRM is available from the National Institute of Standards and Technology, Standard Reference Materials Program, Room 204, Building 202, Gaithersburg, Maryland 20899 (301/975-6776).*

***Reagent Blanks/Bottle Blanks/Blank Spikes*** *- Reagent blanks must not contain more than 5 µg/L arsenic or 25 µg/L lead. Bottle blanks must not contain arsenic and/or lead concentrations greater than 10 and 50 µg/L, respectively. If either the reagent blank or a bottle blank exceeds these values, contamination of reagents, water, or equipment should be suspected. In this case, the laboratory must investigate possible sources of contamination and mitigate the problem before continuing with sample analysis. Blank spikes should be within 15% of their true value. If recovery of any blank spike is outside this range, possible errors in preparation, contamination, or instrument problems should be suspected. In the case of a blank spike outside specified limits, the problems must be investigated and corrected before continuing sample analysis.*

### *Analytical Methods*

*Extraction fluids (from both the stomach-phase and intestinal-phase extractions) were analyzed for metals (antimony, arsenic, beryllium, cadmium, cobalt, copper, lead and nickel). Inductively coupled plasma/mass spectrometry (ICP/MS) (EPA Method 200.8), ICP/atomic emission spectrometry (ICP/AES), and graphite furnace atomic absorption (GFAA) (EPA Method 7060A) were used for the analyses. The laboratory reported arsenic results by GFAA for selected samples because of matrix interference encountered for arsenic during the ICP analyses. Most of the data were reported from the ICP/MS analysis, however, the laboratory used the ICP/AES method for samples in which high levels of target analytes were present. All solid and aqueous/fluid samples were shipped to CAS under chain of custody.*

## Results

The results of the external bioaccessibility testing for metals of concern in the Rodney Street community soils are shown in Tables A5-9 to A5-16. All averages have reported as two significant figures.

## Table A5-9: *In vitro* Bioaccessibility Testing of Antimony

| Ground Soil | | | | |
|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 1.3 | 0.2 | 17 | 0.3 | 21 |
| 1.3 | 0.3 | 21 | 0.5 | 36 |
| 0.5 | 0.2 | 32 | 0.2 | 36 |
| 1.1 | 0.1 | 11 | 0.2 | 15 |
| 1.4 | 0.3 | 19 | 0.4 | 24 |
| 1.2 | 0.3 | 21 | 0.3 | 23 |
| 0.9 | 0.2 | 25 | 0.2 | 26 |
| 3.0 | 0.5 | 18 | 0.9 | 29 |
| 2.2 | 0.2 | 7 | 0.5 | 21 |
| 4.1 | 1.8 | 44 | 2.6 | 64 |
| min | | 7 | | 15 |
| max | | 44 | | 64 |
| [illegible] | | [illegible] | | [illegible] |
| **Sieved Fine Soil** | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 1.3 | 0.2 | 13 | 0.2 | 18 |
| 0.8 | 0.2 | 32 | 0.3 | 39 |
| 3.4 | 0.2 | 5.2 | 0.2 | 6.1 |
| 1.0 | 0.1 | 14 | 0.4 | 42 |
| 1.1 | 0.3 | 28 | 0.4 | 40 |
| 1.4 | 0.5 | 35 | 0.6 | 44 |
| 0.8 | 0.6 | 84 | 0.2 | 31 |
| 2.3 | 0.5 | 23 | 0.8 | 33 |
| 1.5 | 0.1 | 6.6 | 0.3 | 20 |
| 2.4 | 0.8 | 34 | 1.1 | 45 |
| min | | 5.2 | | 6.1 |
| max | | 84 | | 45 |
| **Overall** | | | | |
| min | | 5.2 | | 6.1 |
| max | | 84 | | 64 |

## Table A5-10: *In vitro* Bioaccessibility Testing of Arsenic

| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|
| **round Soil** | | | | |
| 31.8 | 8.6 | 27 | 8.3 | 26 |
| 50.1 | 21.5 | 43 | 23.1 | 46 |
| 30.5 | 8.9 | 29 | 9.2 | 30 |
| 20.4 | 4.5 | 22 | 7.1 | 35 |
| 49.0 | 13.2 | 27 | 10.8 | 22 |
| 29.2 | 5.6 | 19 | 5.0 | 17 |
| 35.3 | 9.9 | 28 | 6.7 | 19 |
| 30.3 | 9.4 | 31 | 5.2 | 17 |
| 37.2 | 19.0 | 51 | 13.4 | 36 |
| 34.4 | 11.4 | 33 | 10.0 | 29 |
| min | | 19 | | 17 |
| max | | 51 | | 46 |
| [illegible] | | 31 | | [illegible] |
| ieved Fine Soil | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 46.0 | 12.4 | 27 | 9.2 | 20 |
| 28.9 | 13.9 | 48 | 13.3 | 46 |
| 38.9 | 10.9 | 28 | 3.3 | 8.5 |
| 19.3 | 5.0 | 26 | 10.8 | 56 |
| 46.7 | 17.3 | 37 | 16.8 | 36 |
| 42.5 | 9.8 | 23 | 5.1 | 12 |
| 20.9 | 7.3 | 35 | 1.9 | 9.2 |
| 31.8 | 11.8 | 37 | 6.0 | 19 |
| 29.1 | 13.7 | 47 | 8.4 | 29 |
| 33.4 | 13.0 | 39 | 7.4 | 22 |
| min | | 23 | | 8.5 |
| max | | 48 | | 56 |
| [illegible] | | [illegible] | | [illegible] |
| **verall** | | | | |
| min | | 19 | | 8.5 |
| max | | 51 | | 56 |
| [illegible] | | [illegible] | | [illegible] |

## Table A5-11: *In vitro* Bioaccessibility Testing of Beryllium

| | | | | |
|---|---|---|---|---|
| Ground Soil | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 0.7 | 0.3 | 42 | 0.08 | 11 |
| 0.5 | 0.3 | 53 | 0.08 | 16 |
| 0.6 | 0.3 | 57 | 0.08 | 14 |
| 0.5 | 0.3 | 48 | 0.08 | 15 |
| 0.8 | 0.4 | 43 | 0.08 | 10 |
| 0.9 | 0.4 | 39 | 0.08 | 8.6 |
| 0.7 | 0.3 | 45 | 0.07 | 9.6 |
| 1.1 | 0.7 | 61 | 0.08 | 7.0 |
| 4.3 | 3.4 | 79 | 0.08 | 1.9 |
| 0.7 | 0.4 | 49 | 0.07 | 10 |
| min | | 39 | | 1.8 |
| max | | 79 | | 15 |
| [illegible] | | [illegible] | | [illegible] |
| Sieved Fine Soil | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 0.8 | 0.4 | 48 | 0.08 | 11 |
| 0.5 | 0.3 | 58 | 0.08 | 16 |
| 0.7 | 0.4 | 59 | 0.07 | 11 |
| 0.5 | 0.3 | 55 | 0.08 | 16 |
| 0.8 | 0.5 | 59 | 0.08 | 10 |
| 1.0 | 0.5 | 51 | 0.08 | 7.8 |
| 0.9 | 0.5 | 58 | 0.08 | 8.8 |
| 1.2 | 0.8 | 70 | 0.08 | 6.8 |
| 4.2 | 3.4 | 81 | 0.08 | 1.9 |
| 0.9 | 0.4 | 52 | 0.08 | 9.4 |
| min | | 48 | | 1.9 |
| max | | 81 | | 15 |
| [illegible] | | [illegible] | | [illegible] |
| Overall | | | | |
| min | | 39 | | 1.9 |
| max | | 81 | | 15 |
| [illegible] | | [illegible] | | [illegible] |

## Table A5-12: *In vitro* Bioaccessibility Testing of Cadmium

| | | | | | |
|---|---|---|---|---|---|
| **Ground Soil** | | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| | 1.5 | 1.0 | 63 | 0.9 | 59 |
| | 1.4 | 1.2 | 83 | 0.7 | 51 |
| | 1.6 | 0.9 | 58 | 1.0 | 62 |
| | 2.3 | 1.6 | 70 | 1.1 | 48 |
| | 2.2 | 1.6 | 69 | 1.1 | 49 |
| | 1.2 | 0.9 | 73 | 0.7 | 56 |
| | 1.8 | 1.2 | 68 | 1.3 | 75 |
| | 4.7 | 3.4 | 72 | 2.8 | 59 |
| | 3.4 | 2.4 | 69 | 0.3 | 9 |
| | 2.5 | 1.9 | 77 | 1.5 | 62 |
| min | | | 58 | | 9 |
| max | | | 83 | | 75 |
| [illegible] | | | [illegible] | | [illegible] |
| **Sieved Fine Soil** | | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| | 2.2 | 1.5 | 68 | 1.2 | 54 |
| | 1.2 | 1.0 | 86 | 0.7 | 57 |
| | 1.5 | 1.0 | 65 | 1.2 | 79 |
| | 2.2 | 1.7 | 78 | 1.5 | 69 |
| | 2.5 | 2.0 | 79 | 1.5 | 59 |
| | 1.9 | 1.4 | 73 | 1.2 | 62 |
| | 1.5 | 1.1 | 74 | 1.2 | 75 |
| | 5.3 | 4.3 | 80 | 3.2 | 60 |
| | 2.4 | 1.7 | 71 | 0.1 | 3.8 |
| | 1.9 | 1.6 | 83 | 1.2 | 63 |
| min | | | [illegible] | | 4 |
| max | | | [illegible] | | 79 |
| [illegible] | | | [illegible] | | [illegible] |
| **Overall** | | | | | |
| min | | | 58 | | 4 |
| max | | | 86 | | 79 |

## Table A5-13: *In vitro* Bioaccessibility Testing of Cobalt

| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|
| **Ground Soil** | | | | |
| 78.6 | 14.9 | 19 | 8.7 | 11 |
| 46.2 | 11.6 | 25 | 7.9 | 17 |
| 63.6 | 16.5 | 26 | 14.6 | 23 |
| 171 | 39.3 | 23 | 30.8 | 18 |
| 113 | 17.0 | 15 | 10.7 | 9.5 |
| 71.7 | 10.8 | 15 | 8.6 | 12 |
| 100 | 18.0 | 18 | 16.0 | 16 |
| 111 | 37.7 | 34 | 27.8 | 25 |
| 56.6 | 10.8 | 19 | 8.5 | 15 |
| 82.3 | 20.6 | 25 | 14.8 | 18 |
| min | | 15 | | 9.5 |
| max | | 34 | | 25 |
| avg. | | [illegible] | | 16 |
| **Sieved Fine Soil** | | | | |
| 109 | 21.8 | 20 | 13.1 | 12 |
| 28.7 | 10.1 | 35 | 6.0 | 21 |
| 72.5 | 23.2 | 32 | 18.9 | 26 |
| 163 | 53.8 | 33 | 12.2 | 7.5 |
| 66.6 | 21.3 | 32 | 12.7 | 19 |
| 90 | 18.9 | 21 | 14.4 | 16 |
| 60.1 | 19.2 | 32 | 14.4 | 24 |
| 102 | 32.6 | 32 | 24.5 | 24 |
| 37.1 | 11.5 | 31 | 8.5 | 23 |
| 65.8 | 15.8 | 24 | 11.2 | 17 |
| min | | 20 | | 7.5 |
| max | | 35 | | 26 |
| [illegible] | | [illegible] | | [illegible] |
| **Overall** | | | | |
| min | | 15 | | 7.5 |
| max | | 35 | | 26 |
| [illegible] | | [illegible] | | [illegible] |

## Table A5-14: *In vitro* Bioaccessibility Testing of Copper

Ground Soil

| | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|
| | 438 | 114 | 26 | 149 | 34 |
| | 359 | 111 | 31 | 176 | 49 |
| | 436 | 166 | 38 | 209 | 48 |
| | 631 | 177 | 28 | 227 | 36 |
| | 880 | 273 | 31 | 370 | 42 |
| | 453 | 149 | 33 | 181 | 40 |
| | 798 | 239 | 30 | 303 | 38 |
| | 601 | 162 | 27 | 240 | 40 |
| | 820 | 3 | 0.4 | 90 | 11 |
| | 520 | 239 | 46 | 255 | 49 |
| min | | | 0.4 | | 11 |
| max | | | 46 | | 49 |
| avg | | | 29 | | 39 |

Sieved Fine Soil

| | [illegible] (µg/g) | [illegible] (µg) | % | [illegible] (µg) | [illegible] % |
|---|---|---|---|---|---|
| | 637 | 178 | 28 | 236 | 37 |
| | 247 | 104 | 42 | 124 | 50 |
| | 592 | 207 | 35 | 255 | 43 |
| | 628 | 232 | 37 | 377 | 60 |
| | 819 | 360 | 44 | 401 | 49 |
| | 656 | 249 | 38 | 282 | 43 |
| | 737 | 280 | 38 | 332 | 45 |
| | 647 | 265 | 41 | 304 | 47 |
| | 494 | 3.4 | 0.7 | 43 | 8.8 |
| | 460 | 207 | 45 | 216 | 47 |
| min | | | 0.7 | | 8.8 |
| max | | | 45 | | 60 |
| [illegible] | | | [illegible] | | [illegible] |

Overall

| | | | | | |
|---|---|---|---|---|---|
| min | | | 0.4 | | 8.8 |
| max | | | 46 | | 60 |
| [illegible] | | | [illegible] | | [illegible] |

## Table A5-15: *In vitro* Bioaccessibility Testing of Lead

| Ground Soil | | | | | |
|---|---|---|---|---|---|
| | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| | 187 | 114 | 61 | 15.7 | 8.4 |
| | 239 | 165 | 69 | 33.5 | 14 |
| | 120 | 94 | 78 | 3.7 | 3.1 |
| | 231 | 176 | 76 | 13.9 | 6.0 |
| | 383 | 260 | 68 | 23.0 | 6.0 |
| | 209 | 134 | 64 | 4.2 | 2.0 |
| | 343 | 240 | 70 | 17.2 | 5.0 |
| | 1030 | 680 | 66 | 36.9 | 3.6 |
| | 838 | 285 | 34 | 14.6 | 1.7 |
| | 911 | 738 | 81 | 79.3 | 8.7 |
| | | | | | |
| min | | | 34 | | 1.6 |
| max | | | 81 | | 14 |
| avg | | | [illegible] | | [illegible] |
| | | | | | |
| Sieved Fine Soil | | | | | |
| | [illegible] (µg/g) | [illegible] (µg) | [illegible] | [illegible] | [illegible] |
| | 232 | 167 | 72 | 8.8 | 3.8 |
| | 211 | 167 | 79 | 12.0 | 5.7 |
| | 190 | 150 | 79 | 7.0 | 3.7 |
| | 222 | 178 | 80 | 21.1 | 9.5 |
| | 430 | 314 | 73 | 20.6 | 4.8 |
| | 389 | 335 | 86 | 14.4 | 3.7 |
| | 320 | 253 | 79 | 12.8 | 4 |
| | 1210 | 1016 | 84 | 48.4 | 4 |
| | 973 | 487 | 50 | 12.7 | 1.3 |
| | 511 | 393 | 77 | 19.9 | 3.9 |
| | | | | | |
| min | | | 50 | | 1.3 |
| max | | | 86 | | 9.5 |
| [illegible] | | | | | |
| | | | | | |
| Overall | | | | | |
| min | | | 34 | | 1.3 |
| max | | | 86 | | 14 |
| [illegible] | | | | | |

## Table A5-16: *In vitro* Bioaccessibility Testing of Nickel

| | | | | |
|---|---|---|---|---|
| Ground Soil | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 5170 | 517 | 10 | 517 | 10 |
| 3130 | 657 | 21 | 657 | 21 |
| 5010 | 852 | 17 | 1002 | 20 |
| 7870 | 944 | 12 | 1023 | 13 |
| 10500 | 945 | 9 | 1050 | 10 |
| 4670 | 514 | 11 | 514 | 11 |
| 9550 | 726 | 7.6 | 879 | 9.2 |
| 4610 | 922 | 20 | 1014 | 22 |
| 5450 | 763 | 14 | 763 | 14 |
| 4750 | 760 | 16 | 713 | 15 |
| min | | 7.6 | | 9.2 |
| max | | 21 | | 22 |
| [illegible] | | [illegible] | | [illegible] |
| Sieved Fine Soil | | | | |
| (µg/g) | actual (µg) | [illegible] | actual (µg) | [illegible] |
| 7310 | 804 | 11 | 804 | 11 |
| 1840 | 515 | 28 | 442 | 24 |
| 5370 | 1074 | 20 | 1074 | 20 |
| 6410 | 1154 | 18 | 1090 | 17 |
| 5620 | 1293 | 23 | 1124 | 20 |
| 5730 | 917 | 16 | 917 | 16 |
| 6200 | 682 | 11 | 744 | 12 |
| 5290 | 1058 | 20 | 1005 | 19 |
| 3040 | 608 | 20 | 638 | 21 |
| 4270 | 769 | 18 | 726 | 17 |
| min | | 11 | | 11 |
| max | | 28 | | 24 |
| [illegible] | | [illegible] | | [illegible] |
| Overall | | | | |
| min | | 7.6 | | 9.2 |
| max | | 28 | | 24 |
| [illegible] | | [illegible] | | [illegible] |

## A5-5 Discussion of Bioaccessibility Studies for Metals of Concern in RSC Soils

The mean percent bioaccessibilities and the range from minimum to maximum values for the MOE and external laboratory tests are shown in Table A5-17. In the case of the external laboratory test results, the highest combined bioaccessibility value for either the acid or neutral pH extractions for both the ground and sieved and the sieved only soil samples is shown. In this context, perusal of Tables A5-9 to A5-16 shows that for arsenic, beryllium, cobalt, lead, cadmium and nickel, the extraction of the metal was greatest under acid conditions, and that under subsequent neutral pH extraction conditions, the overall bioaccessibility of these metals did not change appreciably (arsenic, cobalt, copper, nickel) or was much less (beryllium, lead). This lowered bioaccessibility at neutral pH following an acid extraction suggests that these metals become less available in the small intestine. The other metals (antimony and copper) showed further extraction of the metal under neutral pH subsequent to the acid extraction indicating that the combined acid and neutral pH extraction gives a more realistic value for overall bioaccessibility. The MOE and the external laboratory's bioaccessibility results for cobalt, copper, lead and nickel are comparable.

**Table A5-17: Comparison of Corrected MOE and Exponent Bioaccessibilities (%)**

| [illegible] | MOE Mean (range) | Exponent* Mean (range) Ground & Sieved | Exponent* Mean (range) Sieved Only | [illegible] |
|---|---|---|---|---|
| Antimony | 2.8 (2.1 - 3.9) | 30 (7 - 64)** | 32 (5-84) | 32 |
| Arsenic | 22.8 (12.6 - 28.4) | 31 (17 - 51) | 35 (23-56) | - |
| Beryllium | N/A | 52 (39 - 79) | 59 (2-81) | 59 |
| Cadmium | N/A | 70 (9 - 83) | 76 (4-86) | 76 |
| Cobalt | 19.2 (12.5 - 24.7) | 22 (10 - 34) | 29 (8-35) | 29 |
| Copper | 38.1 (31.8 - 44.4) | 39 (<1 - 49) | 43 (1-60) | 43 |
| Lead | 75.7 (61- 90.3) | 67 (2 - 81) | 76 (10-86) | - |
| Nickel | 16.5 (11.8 - 23.3) | 15 (9 - 22) | 19 (11-28) | 19 |

* = highest bioaccessibility value from either acid or neutral pH extractions

** = based on only 21% recovery from NIST soil standard
N/A = Not Available

The external laboratory (Exponent, 2001) notes that while neither the measured concentrations of metals in the soils nor the bioaccessibility differed significantly between the ground and unground samples, the data suggest that there is a slight trend toward higher bioaccessibility in the unground soil samples. On this basis, and given the small number of samples analysed, the bioaccessibility values used to estimate the intake of metals from ingestion of Rodney Street community soils (Section A3-1.5) were selected from the unground soil sample data set (Table

A5-17). Even though the external laboratory had difficulty extracting and analysing antimony, the highest % bioaccessibility for antimony measured by them was selected. The mean bioaccessibility value was selected to account for the wide range of bioaccessibility values obtained which was assumed to reflect the considerable heterogeneity of the soil samples. Also, in general, the percent metal bioaccessibility decreased with increasing soil nickel concentration. This latter trend is, in part, due to the non-equilibrium conditions involved in simulating processes in the gastrointestinal tract, which are themselves non-equilibrium processes, and, the form or species of nickel present in the soils containing the higher soil nickel concentrations.

There is some information on the bioaccessibility of metals in other soils, however, the emphasis is on arsenic and lead (Ellickson et al., 2001; Ruby et al., 1999; Hamel et al., 1998). Hamel et al., (1998) do provide some information on the acid extraction of cadmium and nickel from a Standard Reference Material (SRM) 2710 from the US National Institute of Standards and Technology (NIST) and nickel in a chromium contaminated soil from Jersey City, NJ. NIST SRM 2710 is a Montana soil with a certified nickel content of 14.3 mg/kg. The percentage bioaccessibility of nickel in the SRM 2710 ranged from 11% to 14%, and was 23% to 40% in the Jersey City soil sample. The external laboratory that performed the bioaccessibility testing also performed the acidic or stomach phase part of the bioaccessibility protocol on another NIST SRM 2711 as part of the validation of their approach. NIST SRM 2711 is also a Montana soil, however, its certified nickel content is 20.6 mg/kg. The results of the acid bioaccessibility testing of SRM 2711 are shown in Table A5-18. Without further information on the speciation of nickel in these other soils, direct comparison with the bioaccessibility of nickel in Rodney Street community soils is difficult.

It should be noted that while concentrations of some metals are certified in NIST SRMs, not all metals have certified concentrations. For example, concentrations of antimony, beryllium and cobalt are not certified. Other publications (Roelandts and Gladney,1998 and Church et al., 1999) report antimony concentrations of 12 mg/kg for NIST 2711, beryllium concentrations of 1.6 to 2 mg/kg, and cobalt concentrations of 9.5 and 12 mg/kg. The external laboratory's analytical procedure resulted in only a 21% recovery of antimony based on the certified value of 19.4 mg/kg. However, as noted another laboratory found 12 mg Sb/kg (Roelandts and Gladney, 1998). This would bring the recovery up to 34.6%, which is still low.

**Table A5-18: Bioaccessibility Testing of Standard Reference Material NIST 2711**

| | Soil | | | Stomach-phase Extraction | |
|---|---|---|---|---|---|
| Metal | Certified Value (mg/kg) | Measured Value (µg/g) | % Recovery of Lab. Analysis | Measured Value (µg/100 mL) | % Bioaccessiblity[1] |
| Antimony* | 19.4 | 4.15 | 21 | 1.59 | 38.3 |
| Arsenic | 105 | 91.1 | 87 | 54.2 | 59.5 |
| Beryllium* | 1.6 | 0.92 | 57.5 | 0.383 | 41.6 |
| Cadmium | 41.7 | 37.7 | 90 | 35.2 | 93.4 |
| Cobalt* | 10 | 7.8 | 78 | 3.5 | 44.9 |
| Copper | 114 | 106 | 93 | 49.1 | 46.3 |
| Lead | 1162 | 1080 | 93 | 864 | 80 |
| Nickel | 20.6 | 15.9 | 77 | 4.08 | 25.7 |

1 = measured value (stomach extract) as a percentage of measured soil value

* = not certified values

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# Appendix 6

# Intake Factors and Receptor Assumptions for the Assessment of the Rodney Street Community

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## A6-0 Intake Factors and Receptor Assumptions

Several sources were considered in selecting the physiological and behaviourial characteristics used to assess the Rodney Street community. These included:

- Compendium of Canadian Human Exposure Factors for Risk Assessment (O'Connor, 1997);
- EPA Exposure Factors Hand Book (US EPA, 1997);
- EPA Dermal Exposure Assessment and Supplemental Guidance (US EPA, 1992; 2000a);
- EPA Child-Specific Exposure Factors Handbook (US EPA, 2000b);
- Environmental Health Directorate Working Group on Reference Values (EHD, 1993);
- Canadian Environmental Protection Act (1994);
- Canadian Council of the Ministers of the Environment (CCME, 1996; 2000);
- Health Canada (1995).

The following sections provide detailed information, in the form of tables and text where appropriate, for each of the receptor parameters utilized in the assessment. Selected values are highlighted and discussed. For the most part, the Compendium of Canadian Human Exposure Factors for Risk Assessment (O'Connor, 1997) was used as a primary source of receptor data. This source was selected since it characterizes Canadian populations and as a result would best represent the Rodney Street community; it relies on published and reliable reference sources, such as Health Canada, Statistics Canada and the Canadian Fitness and Lifestyles Research Institute; and, has been used in the past on several assessments conducted by the Ministry and the CCME. In cases where this data set was unable to adequately describe certain time activity patterns and/or behaviourial/physiological characteristics, other data sources, such as the US EPA Exposure Factors Handbook (US EPA, 1997) were used.

## A6-1 Time Spent in Age Group

As defined by Health Canada (1995) and CEPA (1994), the following age classifications were used for the HHRA:

- Infant (0 to 6 months);
- Preschool child (7 months to <5 years);
- Child (5 years to <12 years);
- Adolescent (12 to <20 years); and
- Adult (20 years and over).

## A6-2 Body Weight

Available body weight data are summarized in Table A6-7a. Mean values provided by O'Connor (1997) and CCME (2000) were selected for the HHRA, as this was the most recent data characterizing the Canadian population, and is similar to other data sources available for the Canadian and U.S. populations.

## A6-3 Inhalation Rate

Inhalation of airborne chemicals is a potential source of chemical exposure for the residents of the Rodney Street community. Available inhalation rate data are summarized in Table A6-7b. Mean values provided by O'Connor (1997) were selected for the HHRA, as this was the most recent data characterizing the Canadian population. It should be noted that this data need not be used in the direct assessment of inhalation toxicity since the dose response factors used in the HHRA to characterize inhalation toxicity are expressed on a concentration basis ($\mu g/m^3$), rather than a dose basis (μg/kg/day), allowing direct comparison of these factors with measured and/or predicted air concentrations. However, inhalation rate data is necessary in the calculation of incremental exposures through this pathway.

## A6-4 Water Intake Rate

Drinking water is municipally supplied in the Rodney Street community with water taken from Lake Erie that is not likely to be directly impacted by contamination in the Port Colborne area. None the less, drinking water is a potential source of exposure to the chemicals of concern in the Rodney Street community. Available water intake data are summarized in Table A6-7c. Mean values provided by O'Connor (1997) were selected for the HHRA, as this was the most recent data characterizing the Canadian population, and is similar to other data sources available for the Canadian and U.S. populations.

## A6-5 Soil Ingestion Rate

The ingestion of soil is a potential source of exposure to chemicals in the Rodney Street community. The potential for exposure to chemicals through inadvertent soil ingestion is greater for children as a result of behavioral patterns present during childhood. Inadvertent soil ingestion among children may occur through the mouthing of objects or hands. This mouthing behavior is considered to be a normal phase of childhood development. Adults may also ingest soil or dust particles that adhere to food, cigarettes, or their hands. Deliberate soil ingestion is defined as pica and is discussed below. Available soil ingestion data are summarized in Table A6-7d. The average soil ingestion rates recommended by the EPA (US EPA, 2000b; 1997) for assessing risks associated with chemicals in soil were selected for the assessment of toddlers and children. Recent publications (Stanek et al., 2001) and past assessment conducted by the MOE are in agreement with the assumptions made in this assessment. Ingestion rates recommended by CCME (1996) and used by MOE in the past were selected for other receptors.

### A-6-5.1 Pica

Deliberate soil ingestion is defined as pica and is relatively uncommon in the general population. The scientific literature define pica as "the repeated eating of non-nutritive substances" (Feldman, 1986); however, for this study, the concern is related to deliberately high soil ingestion. Information on the incidence of soil pica is limited, but it appears that soil pica is not common. Five key tracer studies (Binder et al., 1986; Clausing et al., 1987; Van Wijnen et al., 1990; Davis et al., 1990; and Calabrese et al., 1989) reviewed by the US EPA (1997) revealed only one child out of the more than 600 children involved in these studies ingested an amount of soil significantly greater than the range for other children. These studies did not include data for all populations and were representative of short term ingestion only. However, it can be assumed that the incidence rate of deliberate soil ingestion behavior in the general population is low. US EPA (1997, 2000b) recommend a soil ingestion rate of 10 g/day for children who deliberately ingest soil. However, this value is only intended for use in acute exposure assessments and these exposures cannot be compared with chronic health criteria.

### A-6-5.2 Soil/Dust Ratio Methodology

In the outdoor environment, soil ingestion, hence the intake of various contaminants, represents a significant exposure pathway for children. Studies have shown that soil enters the house as dust by atmospheric transport, as well as being brought into the house by animals and humans on their bodies, clothes or shoes (ATSDR, 1988). While there is adequate evidence of a relationship between the levels of contaminants found outside the homes with those inside the homes, the extent of the relationship is not clear.

Study undertaken by Rutz et al., (1997) suggested that between 20-30% of indoor contamination was from outdoor soil sources. The authors found that the tracking of soil was the primary mechanism for uranium to enter the residence with the re-entrained dust being a factor as well.

The Integrated Exposure Uptake BioKinetic (IEUBK) model used by the EPA for modelling the metal lead has suggested that the mass fraction of soil in indoor dust is related to the level of lead in the outdoor soil concentration by a ration of about 0.7. This means that the indoor lead dust levels on a weight-by-weight basis were designated to be about 0.7 of the outdoor soil level. However, according to the EPA, this value is only a recommended value for input into the IEUBK model in the absence of site-specific data on lead as current information regarding practical techniques to estimate the indoor/outdoor mass fraction ratio are limited. Additionally, it has been noted that lead is not an appropriate model for nickel due to the significant indoor sources of lead in indoor dust.

In the course of this risk assessment, the MOE was provided with a study conducted by PTI Environmental Services (PTI, 1994) at a zinc contaminated site in Bartlesville, Oklahoma. One component of that study was the evaluation of the relationship between the soil concentration and the indoor dust concentration of the metal. This study measured the indoor and outdoor levels of arsenic, cadmium, lead, and zinc and found the ratio of indoor dust level to the soil concentration levels to be 0.20, 0.35, 0.50, and 0.36, respectively.

Recently, a study conducted by Rasmussen et al., (2001) in the city of Ottawa found that dust generated from sources in the house contribute significantly to exposures to elements such as lead, cadmium, antimony and mercury. While the study did consider the indoor and outdoor levels of the aforementioned metals, the study concluded that it would be "difficult-to-impossible" to predict indoor dust concentration based on the low metal levels found in the local soils. Additionally, this study only looked at particles in the 100-250 um size range which is of questionable relevance.

Hwang et al., (1997) and Calabrese (unpublished, as reported in Walker and Griffin, 1997) have undertaken comprehensive studies which in part examine the relationship of interior surface dust levels of arsenic to outdoor soil concentration of arsenic. Both Hwang et al., (1997) and Calabrese (unpublished) sampled interior dust and outdoor soil concentrations using different methodologies from the same subset of 25 households in Anaconda, Montana. The reported average outdoor soil and interior dust concentrations were significantly different, 192 mg/kg and 75.14 mg/kg, respectively from the Hwang et al., study, versus 75 mg/kg and 29 mg/kg from the Calabrese study, respectively. However, the relationship between the average interior surface dust concentration and outdoor soil concentrations were very similar. The ratio of the average interior dust to outdoor soil concentrations were calculated to be 0.391 and 0.387 for the Hwang and Calabrese studies, respectively. These ratios have been validated in a recent study conducted in Deloro, Ontario where indoor dust samples were compared with outdoor soil samples (MOE, 1999).

Calabrese and Stanek (1992) have estimated that 30% of household dust is derived from outdoor soil, with the remaining 70% originating form other sources. Other studies have found similar relationships between outdoor soil and indoor dust concentrations for several metals (Murgueytio et al., 1998).

It was concluded that using the most comprehensive environmental media sampled within the Rodney Street community (outdoor soil) and the relationship described by the Hwang and Calabrese studies above would not only result in the appropriate expression of interior dust levels for use in an exposure assessment, but would also inherently correlate soil and interior dust on a spatial basis. The ratio derived from the Hwang and Calabrese studies (0.39) was selected as it considered metals similar to nickel with respect to the expected relationship of indoor dust and outdoor soil concentrations, it has been validated in a recent Ontario study (MOE, 1999) and it is substantiated by the other studies cited above (Murgueytio et al., 1998; PTI, 1994; Calabrese and Stanek, 1992; Rutz et al., 1997).

Based on Walker and Griffin (1997), it has been assumed that 55% of a receptors soil ingestion rate is allocated to indoor dust exposure, while the remaining 45% is allocated to outdoor soil exposures. The ratio of soil intake to dust intake is not proportional to the ratio of the number of waking hours that a child spends outdoors versus indoors. Children spend only 15 to 30% of their waking hours playing outside but are more likely to be in contact with bare soil areas during this time. The default outdoor:indoor ingestion ratio of 45:55 has been adopted by the US EPA (1994) as an IEUBK model default.

## A6-6 Dermal Routes of Exposure

Dermal exposure can occur during a variety of activities in different environmental media, such as:

- Water (eg., bathing, washing, swimming);
- Soil (eg., outdoor recreation, gardening, construction);
- Sediment (eg., wading, fishing);
- Liquids (eg., use of commercial products);
- Vapors/fumes (eg., use of commercial products); and
- Indoors (eg., carpets, floors, countertops).

For the Rodney Street assessment, only dermal contact with soils and dusts (indoors) are of concern.

### A-6-6.1 Soil Adhesion to Skin

Soil adherence to the surface of the skin is a required parameter to calculate dermal dose when the exposures involving dermal contact with chemicals in soil or dust are of concern. Available soil adhesion to skin data are summarized in Table A6-7e. Adhesion factors reported in the literature vary greatly depending on activity and soil conditions. US EPA (2000b) recommends a default adhesion factor of 0.2 mg/cm$^2$ for children and 0.07 mg/cm$^2$ for adults. These values were selected for the Rodney Street assessment.

### A-6-6.2 Area of Exposed Skin Derivation

In order to calculate the area of exposed skin for various receptors, several methodologies are available. US EPA (1997) recommends an approach where in a moderate climate, 25, 10, 10 and 5% of the whole body surface area is exposed for summer, spring, fall and winter, respectively. Others have considered the surface area of specific body parts considered exposed for each season. Both approaches yield similar results. The latter approach was selected for the Rodney Street assessment, with mean surface areas reported by O'Connor (1997) selected (Table A6-1). Available surface area data are summarized in Table A6-7f. For the Rodney Street community, the following assumptions were made:

- Hands, arms, legs and feet were considered exposed in July and August;
- Hands, arms and legs were considered exposed in June and September;
- Hands and arms were considered exposed in all other months.

**Table A6-1: Mean Percentage of Total Body Surface Area Exposed**

| | Skin Surface Areas in m$^2$ | | | | |
|---|---|---|---|---|---|
| | Receptor | | | | |
| Body Part | Infant | Toddler | Child | Teen | Adult |
| Hands | 0.032 | 0.043 | 0.059 | 0.08 | 0.089 |
| Arms | 0.055 | 0.089 | 0.148 | 0.223 | 0.25 |
| Legs | 0.091 | 0.169 | 0.307 | 0.497 | 0.572 |
| Feet | 0.025 | 0.043 | 0.072 | 0.108 | 0.119 |
| Totals | 0.203 | 0.344 | 0.586 | 0.908 | 1.03 |

## A6-7 Backyard Fruit and Vegetable Consumption

The assessment of potential health risks for people living in the homes on Rodney Street, Port Colborne considers exposures to the metals of concern from all relevant pathways. Eating vegetables grown in backyards where metal levels are above typical levels, represents a potential exposure pathway if the metals present in the soil are taken up into the vegetables. The exposures received by people eating such produce depends upon the concentration of the metals in the vegetables and the amount of vegetables consumed from backyard gardens on an annual basis. Specific data on backyard garden vegetable consumption patterns for the homes on Rodney Street are not available. Therefore it was necessary to estimate likely consumption rates based on studies conducted in other communities in Ontario (MOEE, 1995).

The amounts and types of produce that people might consume from a backyard garden are affected by the size of the garden, the preferences of individuals for the types of crops grown and the yields achieved. In previous risk assessments in other communities, the MOE developed an estimate of backyard garden crop yield of 1.4 kg/m$^2$ for mixed produce (MOEE, 1995). An assumed garden size of 30 m$^2$ was used to provide an estimated total annual yield of 42 kg of produce. These assumptions have been used to estimate backyard garden produce consumption for people living on Rodney Street.

In order to estimate the proportion of home grown produce which is fruit and that which is vegetables, it was first necessary to determine the proportion of fruit and fruit juice consumption which could be derived from a home garden in Ontario. The apparent per capita food consumption rates (Statistics Canada, 1991) indicated that the proportion of fruits consumed by typical Canadians (1988 to 1989) which could be grown in this region of Canada (apples, blueberries, cherries, plums, raspberries, and strawberries) was 37 percent of the total fruit consumption. Thus, a typical adult and child would consume fruit which could be grown in Canada at a rate of 90.65 and 99.16 g/d, respectively (see Table A6-2). All of the vegetables consumed by Rodney Street residents were assumed to be grown in Canada, and therefore, potentially in a home garden. Therefore, the total consumption of fruits and vegetables potentially grown in this region of Canada, and potentially in a home garden, would be 416 and 358 g/d, for adults and children, respectively (ie., 90.65 g/d + 325 g/d; 99.16 + 259 g/d, respectively) (Table A6-2). Thus, the total consumption of potentially home grown fruits and vegetables for a typical family (2 adults, 2 children) would be 565 kg/year (ie., 416 g/d x 365 d/yr x 2 + 358 g/d x 365 d/yr x 2 = 565,000 g/year) (Table A6-3).

Assuming the proportions of fruits versus vegetables in a typical home garden would equal the proportions of potentially home grown fruits and vegetables consumed, as calculated above, this would mean that 26% and 74% of home grown produce would be fruits and vegetables, respectively. Apportioning the backyard garden yield of 42 kg/year between fruits and vegetables would therefore indicate that 11 kg/year (or 26% of 42 kg/year) would be fruits, while 31 kg/year would be vegetables (Table A6-3).

Using the estimated yields of a home garden of 11 and 31 kg/year for fruits and vegetables, respectively, the overall contribution of the home garden to fruit and vegetable consumption, respectively, can be calculated. For a family of four, given a total fruit and fruit juices consumption of 374.5 kg/year and a total vegetable intake of 426.32 kg/year, the proportion potentially obtained from a home garden would be 2.91% and 7.29% for fruits and vegetables, respectively (Table A6-4). This incorporates the assumption that the total yield from the garden is consumed, ie., that there is no loss due to wildlife browsing or spoilage. It should be noted that this calculation, due to its basis on the yield of a home garden, would not take into account the harvesting and consumption of wild fruits such as berries. However, berry consumption is highly seasonal and would comprise a small fraction of the overall fruit consumption, and thus a very small proportion of the total diet. Therefore, it was concluded that consumption of wild berries would contribute negligibly to total intake via home garden produce.

**Table A6-2: Daily Produce Consumption Rates for the Canadian Population**[1]

| | Produce Consumption Rates (g/day) | | | | |
|---|---|---|---|---|---|
| | Infant (0 - 6 mo) | Toddler (7 mo - <5 yr) | Child (5 - <12 yr) | Teen (12 - <20 yr) | Adult (20+ yr) |
| Root Vegetables | 83 | 105 | 161 | 227 | 188 |
| Other Vegetables | 72 | 67 | 98 | 120 | 137 |
| Fruits and Fruit Juices | 136 | 234 | 268 | 258 | 245 |
| % Fruit Locally grown | 37% | 37% | 37% | 37% | 37% |
| Local Fruit | 50.32 | 86.58 | 99.16 | 95.46 | 90.65 |
| Total Daily Consumption of Locally Grown Produce | 205 | 259 | 358 | 442 | 416 |
| Root as a % of Total Daily Local Consumption | 40% | 41% | 45% | 51% | 45% |
| Other as a % of Total Daily Local Consumption | 35% | 26% | 27% | 27% | 33% |
| Local Fruit as a % of Total Daily Local Consumption | 25% | 33% | 28% | 22% | 22% |

1. from O'Connor, 1997.

## Table A6-3: Estimation of Backyard Produce Contribution to Total Produce Consumption

| Receptor | Daily Consumption (g/day) | Number | Total Daily Consumption (g/day) | Days/Year | Total Annual Consumption | |
|---|---|---|---|---|---|---|
| | | | | | g/year | kg/year |
| Adult | 416 | 2 | 832 | 365 | 303,680 | 304 |
| Child | 358 | 2 | 716 | 365 | 261,340 | 261 |
| Annual Family Consumption of Local Produce | | | | | 565,020 | 565 |
| Annual Produce Yield from Backyard Garden[1] | | | | | 42,000 | 42 |
| % of backyard garden - vegetables | | | | | 74% | 74% |
| Annual Vegetable Yield from Backyard Garden | | | | | 31,080 | 31 |
| Total Family Vegetable Consumption (all sources) | | | | | 426,300 | 426 |
| % of backyard garden - fruits | | | | | 26% | 26% |
| Annual Fruit Yield from Backyard Garden | | | | | 10,920 | 11 |
| Total Family Fruit Consumption (all sources) | | | | | 375,500 | 376 |
| % of Annual Vegetable Consumption that comes from Backyard Gardens | | | | | 7.29% | 7.29% |
| % of Annual Fruit Consumption that comes from Backyard | | | | | 2.91% | 2.91% |

1. from MOEE, 1995.

## Table A6-4: Estimated Daily Consumption of Backyard Garden Produce for all Age Groups

| | Produce Consumption Rates (g/day) | | | | |
|---|---|---|---|---|---|
| | Infant (0 - 6 mo) | Toddler (7 mo - <5 yr) | Child (5 - <12 yr) | Teen (12 - <20 yr) | Adult (20+ yr) |
| Total Daily Consumption of Root Vegetables | 83 | 105 | 161 | 227 | 188 |
| % Consumed as Backyard Garden Vegetables | 7.29% | 7.29% | 7.29% | 7.29% | 7.29% |
| Daily Consumption of Backyard Root Vegetables | 6.05 | 7.7 | 11.7 | 16.5 | 13.7 |
| Total Daily Consumption of Other Vegetables | 72 | 67 | 98 | 120 | 137 |
| % Consumed as Backyard Garden Vegetables | 7.29% | 7.29% | 7.29% | 7.29% | 7.29% |
| Daily Consumption of Other Backyard Vegetables | 5.25 | 4.88 | 7.14 | 8.7 | 10.0 |
| Total Daily Consumption of Fruits | 136 | 234 | 268 | 258 | 245 |
| % Consumed as Backyard Garden Fruits | 2.91% | 2.91% | 2.91% | 2.91% | 2.91% |
| Daily Consumption of Fruits | 3.96 | 6.81 | 7.80 | 7.5 | 14.1 |

## A6-8 Time Activity Patterns

The US EPA Exposure Factors Handbook ,Volume III (US EPA, 1997) contains a wide variety of summarized activity pattern statistics for a broad range of categories (ie., gender specific, seasonal, regional, age class, etc.). Data describing the number of minutes spent outdoors (outside the residence) per 24 hour period were used to help define activity values for the residents of the Rodney Street community.

During the two months of summer where toddlers, children and adolescents are not in school, it has been estimated that a receptor may spend up to eight hours/day, seven days/week outside. For the remaining six months of the summer season (for the purpose of characterizing receptor activities, it was assumed that "summer" in Port Colborne included mid March to mid November), receptors were assumed (based on literature estimates) to spend approximately three hours/day, seven days/week outside. The following illustrates the calculations used to estimate the average amount of time spent outside during the summer season.

$$\text{Time}_{\text{avg}} = [(2/8\ \text{months}) * (8\text{hrs}/\text{day} * 7\text{days}/\text{wk})] + [(6/8) * (3.0\text{hrs}/\text{day} * 7\text{days}/\text{wk})]$$

The daily average value has therefore been estimated to be approximately 4.3 hours/day outside in the summer. For winter months, original mean estimates based on literature data were used for these receptors. For infants and adults, literature data was used for both summer and winter. The following table contains the typical mean and plausible maximum daily average values for each receptor. Other available data are summarized in Table A6-7h.

**Table A6-5: Average Time Spent Outdoors During Summer and Winter**

| Receptor Description | Time Spent Outdoors During the Summer* (hours/day) | Time Spent Outdoors During the Winter (hours/day) |
|---|---|---|
| Infant | 3 | 2 |
| Toddler | 4.3 | 2 |
| Child | 4.3 | 2 |
| Teen | 4.3 | 2 |
| Adult | 3 | 2 |

* For the purpose of characterizing receptor activities, it was assumed that "summer" in Port Colborne included mid March to mid November.

Although the amount of time spent outside versus inside should be estimated as accurately as possible, it is not expected to have a great influence on overall exposure estimates. Since exposure from soil ingestion is not proportional to the amount of time a receptor spends outside (Walker and Griffin, 1997), it is expected this variable will have a negligible impact on exposure estimates relative to other parameters.

### A-6-8.1 Amount of Time Spent Within the Rodney Street Community

Typical values have been assigned to the amount of time a receptor may spend in the Rodney Street community, either at home or at parks in the immediate area. The following is a breakdown of the average time assumed to be spent away from the Rodney Street community per day for all receptors (ie., at school and/or work where appropriate). These activity patterns were assumed not to vary significantly throughout the year, except for the two summer months per year which children and adolescents are not in school (July and August). During this time it was assumed these receptors would spend more time within the Rodney Street community (Table A6-6).

**Table A6-6: Average Amount of Time Spent Within the Rodney Street Community Per Day**

| Receptor | Typical | July and August |
|---|---|---|
| Infant | 23 hours/day (1 hour/day) | 23 hours/day (1 hour/day) |
| Preschooler | 23 hours/day (1 hour/day) | 23 hours/day (1 hour/day) |
| Child | 16 hours/day (8 hours/day) | 23 hours/day (1 hour/day) |
| Adolescent | 14 hours/day (10 hours/day) | 23 hours/day (1 hour/day) |
| Adult* | 23 hours/day (1 hour/day) | 23 hours/day (1 hour/day) |

( ) represents the amount of time spent away from the Rodney Street community but still within Port Colborne.
*Adults were assumed to be stay at home parents.

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## Table A6-7a: Body Weight Receptor Parameters

|  |  |  |  |  |  |  |  |  | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | 0-0.5y | 0.5-1 y | 1-1.5 y | 1.5-2 y | 2-2.5y | 3y | 4y | 5-11y | 12-19y | 20+ y |  |
| Time Spent in Age Group | Yrs | 0.5 | 4.5 |  |  |  |  |  | 7 | 8 | 50 |  |
| Body Weight | Kg | 7 | 13 |  |  |  |  |  | 27 | 57 | 70 | CEPA, 1994; Health Canada, 1995; CCME, 1996 |
|  |  | 6.28 F<br>7.20 M | 9.23 F<br>9.83 M | 10.39 F<br>10.7 M | 11.66 F<br>12.5 M | 12.17 F<br>12.69 M | 13.94 F<br>14.85 M | 16.42 F<br>17.14 M | 26.4 F<br>26.4 M | 54.3 F<br>60.1 M | 70 | EHD[1], 1993 |
|  |  | - | 16.5 |  |  |  |  |  | - | - | 70.7 | CCME, 2000 |
|  |  | 8.2 | 16.5 |  |  |  |  |  | 32.9 | 59.7 | 70.7 | O'Connor, 1997 |

| Parameter | Unit | Infant | Toddler |  |  |  |  | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | 0 - 0.5 y | 6-11 mo | 1 y | 2 y | 3 y | 4 y | 5 -11 y | 12 -19 y | 18-74 y |  |
| Time Spent in Age Group | Yrs | 0.5 | 0.5 | 1 | 1 | 1 | 1 | 7 | 8 | 57 |  |
| Body Weight | Kg | n/av | 9.1 | 11.3 | 13.3 | 15.3 | 17.4 | 29.2 | 58.3 | 71.8 | US EPA, 1997[2] |

1. EHD (Environmental Health Directorate Working Group on Reference Values). 1993. Reference Values for Canadian Populations. Updated May 1997. Infant, toddler, and child data are from the Nutrition Canada Survey, 1970-72; teen data are from the Canada Fitness Survey, 1981.
2. US EPA recommended values; from NCHS, 1997; weights include clothing weight estimate 0.09-0.28kg; no body weight value available for infants 0-5 months of age; adult range here is 18 to 74 years of age, thus 18 and 19 year olds are accounted for in both the teen and adult age categories.

EHD and US EPA data presented in this table are summarized from data from individual years.

## Table A6-7b: Inhalation Rate

| Parameter | Unit | Infant | Toddler | Child | | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|---|
| | | 0-0.5y | 0.5-4y | 5-11y | 9-11y | 12-19y | 20+ y | |
| Number of Years Spent in Age Group | Yrs | 0.5 | 4.5 | 7 | - | 8 | 50 | |
| Inhalation Rate | $m^3$ /day | 2 | 5 | 12 | - | 21 | 23 | CEPA, 1994; Health Canada, 1995; EHD, 1993; CCME, 1996 |
| | | - | 9.3 | - | - | - | 16.2 | CCME, 2000 |
| | | 2.1 | 9.3 | - | 14.5 | 15.8 | 15.8 | O'Connor, 1997 |

| Parameter | Unit | < 1 y | 1-2 y | 3-5 y | 6-8 y | 9-11 y | 12-14 y | 15-18 y | 19-65+ y | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of Years Spent in Age Group | Yrs | 1 | 2 | 3 | 3 | 3 | 3 | 4 | 51 | |
| Inhalation Rate | $m^3$ /day | 4.5 | 6.8 | 8.3 | 10 | 14M<br>13F | 15 M<br>12 F | 17 M<br>12F | 11.3 F<br>15.2 M | US EPA, 1997 |
| | | - | - | - | - | - | - | - | 20 | US EPA, 1991[1] |

[1] Adult age range not specified.

## Table A6-7c: Water Intake Rate

| Parameter | Unit | Infant | Toddler | | | Child | | | | Teen | | Adult | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0-0.5y | <1 y | <3 y | 0.5-4y | 1-10 y | 3-5y | 5-11y | 6-17y | 11-19y | 12-19y | 20+ y | |
| Number of Years Spent in Age Group | Yrs | 0.5 | | | 4.5 | | | 7 | | | 8 | 50 | |
| Water Intake | L /day | 0.75 | - | - | 0.8 | - | - | 0.9 | - | - | 1.3 | 1.5 | CEPA, 1994[1]; Health Canada, 1995; CCME, 1996 |
| | | - | - | - | 0.6 | - | - | - | - | - | - | 1.5 | CCME, 2000 |
| | | 0.3 | - | - | 0.6 | - | - | 0.8 | - | - | 1 | 1.5 | O'Connor,1997 |
| | | 0.4/0.8 | - | 0.61 | - | - | 0.87 | - | 1.14 | - | - | 1.49 | EHD[2], 1993 |
| | | - | 0.3 | - | - | 0.74 | - | - | - | 0.97 | - | 1.4 | US EPA, 1997 |
| | | - | - | - | - | - | - | - | - | - | - | 2 | US EPA, 1991[3] |

1. Infants here are non-breast fed; it is assumed that exclusively breast fed infants do not require supplementary liquids.
2. Regarding values quoted for infants, values refer to bottle fed infants consuming concentrated and powdered milk, respectively; adult estimate refers to adults 18 years and older.
3. Adult age range not specified; estimate based on consumption 350 days/year for 30 years.

## Table A6-7d: Soil Ingestion Rate

| Parameter | Units | Infant | Toddler | | | | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0-0.5y | 0.5-4y | <6 y | 1-6 y | 1-7y | 5-11y | 12-19y | 20+ y | |
| Number of Years Spent in Age Group | Years | 0.5 | 4.5 | 6 | 6 | 7 | 7 | 8 | 50 | |
| Soil Ingestion | mg /day | 35 | 50 | - | - | - | 35 | 20 | 20 | CEPA, 1994;<br>Health Canada, 1995 |
| | | - | - | - | - | 70 | - | | 20 | EHD, 1993 |
| | | 20 | 80 | - | - | - | 20 | 20 | 20 | CCME, 1996, 2000 |
| | | - | 100 (best estimate of mean)<br>200 (conservative estimate of mean)- | | | | | - | 50 | US EPA, 1997[1] |
| | | - | 100 (best estimate of mean)<br>400 (upper %ile, short duration)<br>10,000 (pica, acute only) | | | | | - | - | US EPA, 2000b |
| | | - | - | - | 200 | - | - | - | 100<br>(7+ y) | US EPA, 1991[2] |
| | | - | median 24 mg/day (sd = 4 mg/day)<br>95th percentile 91 mg/day (sd = 16.6 mg/day) | | | | | - | - | Stanek et al., 2001 |
| | | 35 | 80 | - | - | - | 80 | 20 | 20 | MOEE, 1995[3] |

1. 100 mg/day is the best estimate of the mean for children under 6 years of age; 200 mg/day may be used as a conservative estimate of the mean; for pica children, 10 g/day is a reasonable value to be used in acute exposure assessments. Adult age range not specified.
2. Used for calculating a 30 year residential exposure; there is a 6 year exposure duration which accounts for the period of highest soil ingestion and lowest body weight (15 kg), followed by a 24 year exposure for older children and adults, using and adult body weight (70 kg).
3. Soil ingestion rates typically used by MOE in assessing risks associated with chemicals in soil.

## Table A6-7e: Soil Adhesion to Skin

| Parameter | Unit | Infant | Toddler | Child | | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|---|
| | | 0-0.5y | 0.5-4y | 5-11y | 6-17y | 12-19y | 20+ y | |
| Number of Years Spent in Age Group | Yrs | 0.5 | 4.5 | 7 | 12 | 8 | 50 | |
| Soil Adhesion to Skin | g /day | 2.2 | 3.5 | 5.8 | - | 9.1 | 8.7 | Health Canada, 1995 |
| | mg /cm$^2$ | - | 0.1 (hands only)<br>0.01 (whole body) | | | | | CCME, 2000 |
| | | - | 0.5 - 1.5 | | | - | 0.58 - 1.40 | US EPA, 1997[1] |
| | | 0.2 | | | | | | US EPA, 1992[2] |
| | | 0.2 | | | | 0.07 | | US EPA, 2000a |

1. Studies cited specify adherence values within the given ranges. Age ranges were not specified.

2. United States Environmental Protection Agency (US EPA), Exposure Assessment Group, Office of Health and Environmental Assessment. Dermal Exposure Assessment: Principles and Applications. EPA/600/8-91/011B. January 1992, Interim Report. Range of values in studies was 0.2 - 1.5 mg/cm$^2$; since this range is derived from hand measurements only, it may overestimate average adherence for the entire exposed skin area; thus, the lower end of this range (0.2) may be the best value to represent an average overall exposed skin and 1 mg may be a reasonable upper limit. Age ranges not specified.

## Table A6-7f: Body Surface Area

| Parameter | Unit | Infant | Toddler | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|
| | | 0-6 months | 7 months- 4 years | 5-11 years | 12-19 years | 20+ years | |
| Number of Years Spent in Age Group | Years | 0.5 | 4.5 | 7 | 8 | 50 | |
| Total Body | m$^2$ | 0.3 | - | - | - | - | CCME, 1996 |
| Head, Arms, Hands & Lower Legs | | - | 0.26 | 0.41 | - | - | |
| Head, Arms & Hands | | - | - | - | 0.43 | 0.43 | |
| Arms | m$^2$ | 0.052 | 0.075 | 0.121 | 0.227 | 0.255 | Health Canada, 1995 |
| Hands | | 0.0185 | 0.035 | 0.048 | 0.081 | 0.091 | |
| Legs | | 0.077 | 0.139 | 0.2705 | 0.518 | 0.582 | |
| Feet | | 0.022 | 0.04 | 0.0725 | 0.113 | 0.1275 | |
| Total (Arms, Hands, Legs, & Feet) | | 0.17 | 0.289 | 0.512 | 0.939 | 1.06 | |
| Arms | m$^2$ | - | | | | 0.412 | EHD, 1993 |
| Hands | | - | | | | 0.082 | |
| Legs | | - | | | | 0.62 | |
| Feet | | - | | | | 0.13 | |
| Total (Arms, Hands, Legs, & Feet) | | - | | | | 1.24 | |

| Parameter | Unit | Infant | Toddler | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|
| | | 0-6 months | 7 months- 4 years | 5-11 years | 12-19 years | 20+ years | |
| Number of Years Spent in Age Group | Years | 0.5 | 4.5 | 7 | 8 | 50 | |
| Hands | $m^2$ | 0.032 | 0.043 | 0.059 | 0.08 | 0.089 | O'Connor, 1997 |
| Arms | | 0.055 | 0.089 | 0.148 | 0.223 | 0.25 | |
| Legs | | 0.091 | 0.169 | 0.307 | 0.497 | 0.572 | |
| Feet | | 0.025 | 0.043 | 0.072 | 0.108 | 0.119 | |
| Total ( Hands, Arms, Legs, & Feet) | | 0.203 | 0.344 | 0.586 | 0.908 | 1.03 | |

| Parameter | Unit | Infant | Toddler | Child | | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|---|
| | | <1 year | 1-4 years | 6 years | 9 years | 12-17 years | 18+ years | |
| Arms (Means) | % | 13.7 | 13.0 - 14.0 | 13.1 | 12.3 | 12.1 - 17.5 | - | US EPA, 1997 |
| Hands (Means) | | 5.3 | 5.3 - 6.07 | 4.71 | 5.3 | 5.11 - 5.68 | - | |
| Legs (Means) | | 20.6 | 23.1 - 27.8 | 27.1 | 28.7 | 30.5 - 33.6 | - | |
| Feet (Means) | | 6.54 | 6.27 - 7.29 | 6.9 | 7.58 | 6.93 - 8.02 | - | |
| Total (Arms, Hands, Legs, & Feet) | | 46.1 | 47.7 - 55.2 | 51.8 | 53.9 | 54.6 - 64.8 | - | |
| Exposed Parts of Body | % | In moderate climates, it may be reasonable to assume that 5% of the skin is exposed during the winter, 10% during the spring and fall, and 25% during the summer. | | | | | | |

| Parameter | Unit | Toddler | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|
| | | 2-4 years | 5-11 years | 12-17 years | 18+ years | |
| Arms (Means) | m$^2$ | - | -- | - | 0.219 | US EPA, 1997; US EPA, 1992 |
| Hands (Means) | | - | -- | - | 0.0793 | |
| Legs (Means) | | - | -- | - | 0.497 | |
| Feet (Means) | | - | -- | - | 0.105 | |
| Total (Arms, Hands, Legs, & Feet) (Means) | | - | - | - | 0.9 | |
| Total Body (Medians) | | 0.579 - 0.731 | 0.779 - 1.30 | 1.34 - 1.80 | 1.815 | |

| Parameter | Unit | Toddler | | Child | | | | Teen | | Adult | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 y | 3-5 y | 6 y | 6-8 y | 9 y | 9-11 y | 12-14 y | 15-17 y | 18+ y | |
| Arms (Males Only) | m$^2$ | 0.096 | - | 0.11 | - | 0.13 | - | - | - | 0.23 | US EPA, 1989 (medians) |
| Hands (Males Only) | | 0.04 | - | 0.041 | - | 0.057 | - | - | - | 0.082 | |
| Legs (Males Only) | | 0.18 | - | 0.24 | - | 0.31 | - | - | - | 0.55 | |
| Total Body (Males & Females) | | - | 0.72 | - | 0.925 | - | 1.16 | 1.49 | 1.68 | 1.82 | |

## Table A6-7g: Fruit and Vegetable Consumption

| Parameter | Unit | Infant | Toddler | Child | Teen | Adult | | | Source |
|---|---|---|---|---|---|---|---|---|---|
| | | 1-2 y | 3-5 y | 6-11y | 12-19 y | 20-39 y | 40-69 y | 70+ y | |
| Number of Years Spent in Age Group | Years | | | | | | | | |
| Backyard - Fruits | g/kg/day | 8.74 | 4.07 | 3.59 | 1.94 | 1.95 | 2.66 | 2.25 | US EPA, 1997 |
| | | All Ages: 2.31 (central city), 2.41 (non-metro), 3.07 (suburb), 2.68 (all groups) 1.05 (suburb in northeast), 0.929 (all groups in northeast) | | | | | | | |
| | g/day | 42 (reasonable worst case) (ages not specifed) | | | | | | | US EPA , 1991 |
| Backyard - All Veg. | g/kg/day | 5.2 | 2.46 | 2.02 | 1.48 | 1.47 | 2.07 | 2.51 | US EPA, 1997 |
| | | All Ages: 1.40 (central city), 2.68 (non-metro), 1.82 (suburb), 2.08 (all groups) 3.05 (non-metro northeast), 1.59 (suburb northeast), 1.78 (all groups northeast) | | | | | | | |
| | g/day | 80 (reasonable worst case) (ages not specified) | | | | | | | US EPA , 1991 |
| Backyard - Exposed Veg | g/kg/day | 3.48 | 1.74 | 1.39 | 1.07 | 1.05 | 1.6 | 1.68 | US EPA, 1997 |
| | | All Ages: 1.11 (central city), 1.87 (non-metro), 1.35 (suburb), 1.52 (all groups) 1.65 (all groups in northeast) | | | | | | | |
| Backyard - Protected Veg | g/kg/day | 2.46 | 1.3 | 1.1 | 0.776 | 0.762 | 0.93 | 1.05 | US EPA, 1997 |
| | | All Ages: 0.996 (central city), 1.07 (non-metro), 0.926 (suburb), 1.01 (all groups) 0.701 (all groups in northeast) | | | | | | | |
| Backyard - Root Veg. | g/kg/day | 2.52 | 1.28 | 1.32 | 0.937 | 0.874 | 1.13 | 1.22 | US EPA, 1997 |
| | | All Ages: 0.749 (central city), 1.43 (non-metro), 1.06 (suburb), 1.16 (all groups) 0.838 (all groups in northeast) | | | | | | | |

| Parameter | Unit | Infant | Toddler | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|
| | | 0-0.5 y | 0.5-4 y | 5-11 y | 12-19 y | 20+ y | |
| Number of Years Spent in Age Group | Years | 0.5 | 4.5 | 7 | 8 | 50 | |
| Backyard - Root Veg. | g/day | 8.18 | 10.3 | 15.9 | 22.4 | 19.3 | MOEE, 1995 |
| Backyard - Other Veg. | g/day | 7.09 | 6.6 | 9.65 | 11.8 | 14.1 | MOEE, 1995 |
| Backyard - All Veg. | kg/harvest | 22.8 | | | | | Gradient, 1995 |
| Parameter | Unit | Child | | | | Adult | Source |
| | | 1-4 y | | | | 20+ y | |
| Number of Years Spent in Age Group | Years | | | | | | |
| Backyard - All Fruits & Veg. | g/day | 26 | | | | 34 | MOEE, 1994[1] |
| Parameter | Unit | Infant | Toddler | Child | Teen | Adult | Source |
| | | 0-0.5 y | 0.5-4 y | 5-11 y | 12-19 y | 20+ y | |
| Number of Years Spent in Age Group | Years | 0.5 | 4.5 | 7 | 8 | 50 | |
| Root Veg. | g/day | 83 | 105 | 161 | 227 | 188 | O'Connor, 1997 |
| Other Veg. | g/day | 72 | 67 | 98 | 120 | 137 | O'Connor, 1997 |

| Parameter | Unit | Infant | Toddler | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|
| | | 0-0.5 y | 0.5-4 y | 5-11 y | 12-19 y | 20+ y | |
| All Veg. | g/day | 42 | 125 | 198 | 250 | 250 | Health Canada, 1995<br>CEPA, 1994<br>EHD, 1993 |
| Veg. | g/day | 200 (ages not specified) | | | | | US EPA, 1991 |
| Fruits & Juices | g/day | 136 | 234 | 268 | 258 | 245 | O'Connor, 1997 |
| Fruit & Fruit Products | g/day | 112 | 189 | 202 | 160 | 186 | EHD, 1993<br>Health Canada, 1995<br>CEPA, 1994 |
| Fruit | g/day | 140 (ages not specified) | | | | | US EPA, 1991 |

1. Calculated as totals of all food group types consumed.

## Table A6-7h: Activity Patterns

| Parameter | Unit | Infant | Toddler | Child | Teen | Adult | Source |
|---|---|---|---|---|---|---|---|
| | | 0-0.5 year | 0.5-4 years | 5-14 years | 15-19 years | 20+ years | |
| Number of Years Spent in Age Group | Years | 0.5 | 4.5 | 10 | 5 | 50 | |
| Time Spent Outdoors | Min/Day | - | - | - | 85 | 85 | O'Connor, 1997 |
| Parameter | Unit | Infant | Toddler | Child | Adult | | Source |
| | | 0-0.5 year | 0.5-2 years | 3-11 years | 12+ years | | |
| Number of Years Spent in Age Group | Years | 0.5 | 2.5 | 9 | 58 | | |
| Time Spent Outdoors | Hour/Day | - | - | 5 (weekdays)<br>7 (weekends) | 1.5 | | US EPA, 1997 |

# Appendix 7

## Dermal Uptake Coefficients for Metals

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## A7-1 Dermal Uptake Coefficients for Metals

Daily contact with metals through soil present on the skin represents a potential route of exposure. However, the insoluble nature of most metals in soil limits their bioaccessability for uptake into and through the skin. Where data is available, it shows that dermal uptake of metals is low (Paustenbach, 2000). The rate at which a metal is taken up into the outer layers of the skin is referred to as the *dermal uptake coefficient* (DUC). Studies of the dermal absorption of nickel have suggested that the outer layer of the skin, the stratum corneum, can act as a collector for dermally applied nickel before it enters the underlying tissue (Fullerton et al., 1992). While there is little information available in the scientific literature on dermal uptake of the other metals of concern in this assessment, it is reasonable to assume that similar mechanisms will govern their absorption into the body. This process can be considered to be equivalent to ingestion or inhalation intakes where the material is delivered into the gut or lungs, but cannot be considered to have entered the body proper until it is absorbed through the gut or lung lining and into the underlying tissue or blood.

Therefore, for the purposes of this assessment, dermal uptake coefficients will be used to estimate the amount of each metal that could be delivered to the skin through contact with soil (referred to as *Dermal Intake*). The calculation of dermal intakes for each metal is provided in Appendix 3.

Dermal absorption studies typically use exposure periods extending well past 24 hours. However, the amount of time a human receptor is in contact with a chemical/soil mixture on the skin should correspond with soil contact times normally encountered (US EPA, 1992). In real life situations soil is likely to remain in contact with the skin for only a few hours. Consequently, dermal intake estimates from studies with longer than 24 hours are likely to overestimate normal human exposures.

Metal specific dermal uptake coefficients have been identified for two of the six metals (cobalt and nickel) considered in the detailed exposure assessment. The selection of the dermal uptake coefficient for each metal is discussed below.

## A7-2 Dermal Uptake Coefficient for Nickel

Studies of how nickel can penetrate the skin in humans and animals are limited. Only studies of intact organisms where nickel is measured in blood or urine can show whether nickel has penetrated through the skin layers into the bloodstream. This is important since permeation of nickel into the upper layers of the skin does not automatically mean that nickel has been absorbed into the body. Similarly, contact dermatitis reactions following dermal application of nickel solutions may not imply complete penetration but only irritation of the deep layers of the skin. There are few studies that address the uptake of nickel through human skin available in the literature. Human studies may be separated into application of nickel to intact skin in individuals (Norgaard, 1955, 1957), and, *in vitro* studies with excised human skin in diffusion cells (Fullerton et al., 1986, Fullerton et al., 1992, Frankild et al., 1995, Samitz and Katz, 1976). In addition, reviews are available (ATSDR, 1997, Hostynek et al., 1993). The available studies on nickel uptake in human skin have focused primarily on the uptake of nickel and its relationship with nickel contact dermatitis (Norgaard, 1955; Fullerton et al., 1986; Fullerton et al., 1992; Frankild et al., 1995; Samitz and Katz, 1976).

### A7-3 Intact Skin Studies

These studies have examined the uptake of soluble forms of nickel into the outer layers of the skin. Two types of study protocols are used to measure dermal uptake; studies where nickel compounds were applied to skin and secured with some form of patch, occluding the skin and studies where the applied material were not secured with a patch. Norgaard applied aliquots of radioactive $^{57}$Ni to the forearm. This area was occluded and the radioactivity measured by placing the counter directly over the treated area. Loss of radioactivity with time was interpreted as resorption through the skin, however, no measures of radioactivity in blood or urine were taken. On this basis, dermal uptake rates that ranged between 55% and 77% over a 24 hour period when nickel sulphate was applied to occluded skin reported (Norgaard, 1955). However, it could not be determined if the nickel in this study was actually bound in the outer layers of the skin (ATSDR, 1997). This limits the utility of the study for assessing dermal absorption of nickel compounds.

### A7-4 *In vitro* Studies of Excised Skin

Nickel diffusion through excised cadaver skin was studied using $^{63}$Ni (as nickel sulphate) (Samitz and Katz, 1976). The diffusion of nickel (0.001 M to 0.1M) from physiological saline or human sweat through the epidermis was slight. However, considerable amounts of nickel were bound to the epidermis. No diffusion of nickel through the epidermis took place within 5 hours, even after 48 hours, less than 0.1% of the nickel diffused through the skin. The excised epidermis does not seem to have been occluded.

In a study that applied nickel chloride to excised human skin, Fullerton et al., (1986) reported that 0.23% of the applied dose was absorbed over a 144 hr period in unoccluded skin while 3.5% was absorbed by occluded skin. In a follow-up study designed to determine the efficacy of different vehicle carriers for dermal patch testing, Fullerton et al., (1992) reported that dermal uptake of nickel sulphate in excised human skin, ranged between 3% and 5% of the applied dose in occluded skin over a 93 hr testing period. The study further showed that the level of absorption was dependent on the carrier vehicle used, and that the dermal absorption of dissolved nickel was greater than that of undissolved or crystalline nickel (Fullerton et al., 1992). Analysis of nickel levels in the stratum corneum, epidermal, and dermal layers of skin also showed that the outer stratum corneum layer held the highest levels of nickel. The study also found that little nickel was able to penetrate through all layers of the skin to the underlying tissue (Fullerton et al., 1992). The authors suggest that this layer of the skin may act as a reservoir for nickel that could allow nickel to move into other tissue and that as the level of nickel increases in this layer, subsequent exposures would allow greater amounts of nickel to move through the skin (Fullerton et al., 1992).

Frankild et al., (1995) examined the time- and dose-related effect of the detergent, sodium lauryl sulphate (SLS), on *in vitro* percutaneous penetration of radio labelled $^{63}$Ni chloride in excised human cadaver skin. Simultaneous application of SLS (0.25%, 2% and 10%) and nickel chloride resulted in a significant dose response relationship between SLS concentration and penetration of nickel. Inspection of the data indicates that as in the studies reported by Fullerton et al., (1986, 1992), no penetration occurred over the first 48 hours of the experiments, and all the SLS-mediated penetration occurred after 48 hours. No penetration of nickel chloride occurred in the SLS free controls (Frankild et al., 1995).

This information suggests that while soluble nickel may accumulate in the upper layers of the skin in the initial 48 hours, penetration, if any, does not occur until later. In the context of nickel in soil in contact with the skin for periods of less than 24 hours, assuming normal hygiene, it is difficult to make a case for any dermal penetration of nickel. Consequently, prorating dermal penetration rates based on cumulative penetration after 69 hours or 96 hours *in vitro* exposures will overestimate dermal nickel intake estimates. As pointed out by Frankild et al., (1995), *in vitro* skin models are limited in that the metabolic pathways of the skin and normal repair mechanisms are not functioning.

It should be stressed that the work of Fullerton et al., in 1992 was conducted with occluded skin. This is not representative of dermal contact with soil where exposures would not be expected to last for more than 24 hours. Further, Hostynek et al., (1993) note that occlusion increases skin penetration ten fold over unoccluded conditions. The authors further note that sweat contains significantly higher levels of nickel than normal blood serum and that it is a significant excretory pathway for the metal (Hostynek et al., 1993). Thus, it would appear that dermal absorption of nickel from soil is likely to be very limited and that much of what is absorbed into the outer layers of the skin is likely to be lost from the skin due either to removal in sweat or through the normal loss of outer skin cells from the stratum corneum.

The study using unoccluded skin most closely resembles the dermal exposures to nickel in soil that could be expected in the Rodney Street community. Therefore, the absorption factor of 0.23%, reported by Fullerton, et al., (1986) was used to develop a dermal uptake coefficient for nickel in Port Colborne.

As noted above, Fullerton et al., 1986 reported that 0.23% (0.0023) of an applied dose of nickel chloride was absorbed over a period of 144 hours. However, bathing activities can be expected to limit skin contact with nickel bearing soil to a maximum of 24 hours. Therefore, it is necessary to correct the uptake coefficient reported by Fullerton et al., (1986) to account for the difference in the expected exposure duration of 24 hours and the 144 hours used in the Fullerton study. In developing a corrected dermal uptake coefficient for nickel oxide, it has been assumed that soil would remain in contact with the skin for a period of 24 hours before being removed by bathing activities. The derivation of dermal uptake coefficient for nickel is shown in equation A7-1.

**Eq A7-1:**

$$DUC_{Ni} = 0.0023 * \left(\frac{24 hours}{144 hours}\right) = 0.00038 = 3.8X10^{-4}$$

Where: $DUC_{Ni}$ = Dermal Uptake Coefficient for nickel
24 hrs = Expected exposure duration
144 hrs = Duration of experimental exposure
0.0023 = Reported dermal absorption of Nickel Chloride

It should be noted that this approach assumes a linear relationship between the length of exposure and the amount of nickel available to the skin for absorption. It should also be noted that there is a marked difference in water solubilities between the nickel chloride used by Fullerton et al., (1986) and nickel oxide which is the predominant form of nickel found in the soil on Rodney Street and elsewhere in Port Colborne. Reported solubilities are 642 g/L and 0.0011 g/L for nickel chloride and nickel oxide respectively (ATSDR, 1997). Further, the nickel chloride used by Fullerton et al., was applied in solution and was freely available for absorption by the skin. In Port Colborne, the nickel oxide is associated with soil particles and must dissociate (dissolve) from the soil particles before it is available for absorption by the skin. Therefore, using a dermal dose factor derived for dissolved nickel chloride to estimate the dermal dose of undissolved nickel oxide, will significantly overestimate the amount of nickel oxide available for absorption by the skin. Thus, the $DUC_{Ni}$ factor selected for use at Rodney Street in Port Colborne will provide conservative estimates of dermal exposure for all age groups considered in the assessment.

### Dermal Bioaccessibility

For the NiO in the soil to become available for penetration through the layers of the skin, the nickel has to be in a soluble form. The NiO in the soil may dissolve to some degree in the layer of sweat on the skin during perspiration. The soil bioaccessibility testing (Appendix 5) includes data obtained by incubating soil for four hours at neutral pH (pH 7) under conditions where the soil was about 1/100th the extraction fluid. This is not equivalent to extraction in synthetic sweat but may indicate some estimate of the soluble nickel available to penetrate the skin. The results of the oral bioaccessibility testing indicate that nickel in Rodney Street soils is not readily available at neutral pH. This information and the data of Fullerton et al., (1986), Frankild et al., (1995) and Samitz and Katz, (1976) indicating that nickel ions do not penetrate the upper layers of human skin for at least 48 hours support the DUC factor selected for RSC soils.

## A7-5 Dermal Uptake Coefficient for Cobalt

Paustenbach (2000) cites a dermal uptake coefficient of 0.0004 for cobalt chloride. Information on the cobalt species present in Rodney Street soil is not available. Therefore, it has been assumed that the dermal uptake coefficient for cobalt chloride is representative of the dermal uptake coefficient for cobalt in soil in the Rodney Street community.

## A7-6 Dermal Uptake Coefficients for Antimony, Beryllium, Cadmium and Copper

Dermal uptake coefficients for the remaining metals are not available. In the absence of such values, a default value of 0.01 is recommended by the US EPA for assessing dermal exposure to inorganic compounds such as metal salts (US EPA, 1992). However, this recommendation is based on the conservative assumption that all metal delivered to the skin is available for uptake into the skin. Sweat contains many electrolytes (mainly sodium chloride, potassium and calcium salts), urea and lactic acid. The primary secretion is similar to plasma and initially would have a neutral to slightly acidic pH. Artificial sweat solutions contain high levels of NaCl (around 10%) and lactic acid (around 5%), with a pH of about 5. An adult man secretes 650 mL/day (50 to 1600 mL/day). As noted elsewhere in this report, the amount of each metal that could be released for the soils from Rodney Street, under acidic and neutral pH conditions has been assessed (Appendix 5). For all metals, maximal % bioaccessibility occurred at acid pH. Assuming a slightly acidic (pH 5) sweat layer on the skin, the bioaccessibility of these metals from soil in contact with the skin is likely to be much less than the maximal % bioaccessibility under more acidic (pH 1.5) conditions. These values represent an over estimate of the amount of each metal that could be expected to be released from the soil while in contact with skin. Therefore, the most recent default values for dermal absorption recommended by US EPA Region III (US EPA, 1995) have been used as the dermal uptake coefficients for estimating dermal exposure to these metals.

The dermal uptake coefficients used in this report are summarized in Table A7-1.

**Table A7-1: Dermal Uptake Coefficients**

| | Antimony | Beryllium | Cadmium | Cobalt | Copper | Nickel |
|---|---|---|---|---|---|---|
| Coefficient | 0.01 | 0.01 | 0.01 | 0.0004 | 0.01 | 0.00038 |

## A7-7 References

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# Appendix 8

## Statement of the Peer Review Panel

## Statement of the Peer Review Panel:

The draft document entitled *Soil Investigation and Human Health Risk Assessment for the Rodney Street Community, Port Colborne: October 2001*, and the report entitled *Recommendations and Conclusions from the International Expert Panel Meeting*, as received October 12, 2001, together with revisions addressing verbal comments tabled in the teleconferences held on October 16 and October 19, 2001, appropriately address the issues raised at the expert panel meeting held in Toronto, Ontario on September 20 - 21, 2001.

Dr. John Wheeler,
Atlanta, Georgia

Dr. Ambika Bathija,
Washington, D.C.

Dr. Lynne Haber,
Cincinnati, Ohio

Dr. Tor Norseth,
Oslo, Norway

Dr Rosalind Schoof,
Mercer Island, Washington

Dr. Robert Jin
Toronto, ON

Note: In the report by the international peer review panel the Ministry has inserted its responses to the recommendations made by the panel which arose from the September 20 - 21, 2001 meeting.

# Recommendations and Conclusions From the International Peer Review Panel Meeting

## Meeting to review the Draft Revised Human Health Risk Assessment of the Rodney Street Community completed by the Ontario Ministry of the Environment (OMOE)

**Radisson Plaza Hotel Admiral**
**Toronto, Ontario, Canada**
**September 20 and 21, 2001**

The Ontario Ministry of the Environment assembled a panel of internationally recognized scientists to conduct a peer review of the Ministry's draft report entitled *Soil Investigation and Human Health Risk Assessment for the Rodney Street Community: Port Colborne (Revised 2001)*(hereinafter referred to as the Revised 2001 HHRA Study). The Panel's recommendations and conclusions from the review of the study primarily focus on nickel, and are summarized in the following consensus statements.

### Statement as to Conflict of Interest:

The members of the assembled International Peer Review Panel have declared they have no existing conflict of interest with respect to review of this assessment. They are not employed by, under contract to, or received monies from INCO with respect to the matter under review.

### Overall Conclusion:

The International Peer Review Panel concluded that:

- In general, the methods followed in the study are consistent with the currently generally accepted risk assessment paradigm.
- The Panel supports the process and methodology as applied for the purpose of the Rodney Street Assessment.
- A number of specific revisions were recommended by the Panel and are outlined below in this recommendations and conclusions document.
- The Panel came to consensus on the set of data and parameters which should be used for establishing a soil intervention level for nickel for the Rodney Street Community.
- The available scientific data on dermal sensitization are inadequate to estimate a soil intervention level that would protect sensitized individuals from nickel dermatitis, or that would protect people from being sensitized to nickel.
- The additional analyses on nickel speciation and bioavailability conducted for the Revised 2001 HHRA study improved the confidence and reduced uncertainties in interpreting the results of the assessment. This is a significant contribution to the site-specific risk assessment methodology for nickel.

### Major Strengths Identified by the International Peer Review Panel

The following major strengths of the Revised 2001 HHRA Study were noted by the International

Peer Review Panel:

- The methodology described in the report of Revised 2001 HHRA Study provided a clear, easily followed outline of how the risk assessment process is currently used by regulatory agencies to develop intervention levels of chemicals and metals in various environmental media that are considered protective of human health.
- The multi-media, multi-pathway approach followed in the Revised 2001 HHRA Study was appropriate and clearly described.
- The speciation analysis of nickel appropriately evaluated the forms of nickel present in the community, and the implications of that speciation on nickel exposure in the risk assessment.
- The assessment of bioaccessibility/bioavailability of nickel from Rodney Street Soils was properly conducted. The estimate of the relative bioavailability of soil nickel *versus* soluble nickel was accurately incorporated into the risk assessment.
- The Reference Dose (R*f*D) of 20 micrograms per kilogram body weight per day (US EPA) was considered to be appropriate and protective of human health.
- The Revised 2001 HHRA Study accurately demonstrated that oral exposure was the major exposure pathway of concern for nickel in soils and that inhalation and dermal exposure pathways had a minor contribution to the intake of total nickel from soils.

## Action Items Recommended by the International Peer Review Panel

The International Peer Review Panel recommends that the following action items should be addressed in the Revised 2001 HHRA Study:

### 1. Oral Toxicity and Exposure Criteria

**1.1** There is uncertainty in the extrapolation to humans of effects arising from nickel exposure in laboratory studies, both in the concordance of endpoints and in the determination of appropriate intake criteria. These uncertainties, and the relevance to humans of the endpoints in animal studies should be discussed in greater depth.

*Response: Addressed in chapter 6 (Main document) and Appendix 2 (section A2-1).*

**1.2** The Review Panel considers the US EPA RfD of 20 ug Ni/kg/day appropriate for use in this study. The confidence in this RfD was increased by the findings of a recent two-generation reproduction study where rats were exposed to nickel sulphate hexahydrate (Springborn, 2001). This study addresses a key data gap in the data used for the development of the current US EPA RfD value. A preliminary RfD of 20 ug Ni/kg/day based upon the Springborn (2001) study is under review by the US EPA. These issues should be discussed in the overall strengths and uncertainty analysis of the assessment.

*Response: Addressed in Appendix 2 (section A2-9.2.2 and A2-9.3.2).*

**1.3** Some of the toxicological endpoints attriutable to nickel in laboratory studies using animals (*e.g.*, systemic effects on b and A2-ody weight) have not been evaluated in epidemiological studies of workers exposed to high levels of nickel. However, some similarities have been observed in sensitive endpoints in both laboratory animals and humans (*e.g.*, possible adverse reproductive outcomes in female workers in the nickel refiningindustry and in reproduction toxicity observed in laboratory studies in animals exposed to nickel). A discussion of these issues should be included in the uncertainties section in the revised document.

*Response: Addressed in Appendix 2 (section A2-1).*

**1.4** The rationale for application of uncertainty factors typically used in risk assessment to establish regulatory exposure criteria would be most useful in the methodology section (Appendix 2). This documentation could then be referred to in the main text of the report, and in the discussion of strengths and uncertainties of the overall assessment.

*Response: Addressed in Appendix 2 (section A2-1).*

**1.5** All the RfDs and equivalents are expressed as ug Ni/kg/day, so a conversion to nickel sulphate is not required for the TERA value. The text in the draft report should be modified appropriately to correct this issue.

*Response:This issue has been addressed in the oral exposure limit sections of Appendix 2. However, due to the way inhalation exposure limits are described, it has not been addressed for those limits. This issue is being addressed.*

**1.6** The existing discussion of the rationale for different regulatory exposure values by various agencies (e.g., US EPA, Health Canada, WHO) should be expanded by adding information from the Springborn (2001) study, and develop an appropriate discussion of the rationale for the selection of criteria used in the OMOE's assessment.

*Response: Addressed in Appendix 2 (section A2-9.2.2 and A2-9.3.2).*

**1.7** It should be clearly stated in the uncertainty discussion (in addition to the discussion in Appendix 2) that the EPA definition of an RfD provides a recommended exposure criteria estimate within an order of magnitude. This uncertainty impacts the degree of confidence in the selected soil intervention level.

EPA's IRIS database provides the following definition of an RfD: "In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime."

*Response: Addressed in Appendix 2 (section A2-1).*

## 2. Inhalation Toxicity and Exposure Criteria

**2.1** It is recommended that inhalation risk estimates should be calculated and discussed using the EPA, WHO and Health Canada cancer potency factors for inhalation of nickel. This information will provide an estimate of the range in predicted risks based on current regulatory exposure criteria. It is important to indicate that the regulatory potency criteria are primarily developed to ensure the safety and the health of the public. The estimates of occupational exposures associated with cancers, as documented in various epidemiological studies, should be contrasted with the estimated inhalation exposures from the Rodney Street assessment. A discussion of this comparison is needed to provide a rationale for the conclusion that health risks from inhalation exposures based on the Rodney Street data are minimal.

*Response: Addressed in section 5.6.2 (Main document) and Appendix 2 (sections A2-9.2.3.2 and A2-9.3.1).*

**2.2** The discussion in the uncertainty analysis of the cancer assessment, particularly in the estimates of exposure in the epidemiological studies used to derive the cancer slope factor, requires further discussion.

*Response: Addressed in Appendix 2 (section A2-9.3.1).*

**2.3** Impacts of particle size on deep deposition of nickel into the lungs, resulting in higher tissue dose, requires expanded discussion. The cancer slope factor for nickel refinery dust is based on lung cancer, not nasal or total cancer. Therefore, a discussion of the issue of particle size and degree of penetration into the lungs is important.

*Response: Addressed in Appendix 2 (section A2-9.2.1.1).*

**2.4** Using nickel concentrations in air expressed as TSP (total suspended particulate) rather than $PM_{10}$ (particulate matter less than 10 microns in diameter) is more appropriate because the cancer unit risk values are based on nickel refinery dusts of variable sized particles, including a significant fraction of large particles. The recent, preliminary air monitoring from the Rodney Street area should be presented and discussed to demonstrate OMOE's due diligence on this issue.

*Response: Addressed in section 5.6.2 (Main document) and Appendix 2 (section A2-9.2.1.1).*

**2.5** The statement in the document that the inhalation cancer risks are 10-fold (an order of magnitude) lower than those calculated based upon the Health Canada value should be removed.

*Response: Done.*

**2.6** Information on nickel concentrations in ambient air from other locations in Canada/North America will help put the air nickel concentration data from the Rodney Street Community into context.

*Response: Due to delays in verifying what sort of air sampling equipment was used and the importance of comparing air monitoring data appropriately (discussed in Appendix 2 (section A2-9.2.1.1), this information was not ready for inclusion in the current draft. This issue is being addressed.*

**2.7** The Panel agreed with the following items, but recommended a more detailed discussion be added to the report for clarification:

**2.7.1** The air pathway is insignificant in the systemic dose calculation. Nonetheless, this pathway was included in the current assessment.

*Response: Addressed in section 4.3.3 (Main document).*

**2.7.2** Because the link between soil levels and ambient air concentrations cannot be reliably estimated, the cancer risk from inhalation exposure was appropriately not used to derive the soil intervention level.

*Response: Addressed in section 7-1 (Main document).*

## 3. Market Food Basket and Home Garden Data

### *Market Food Basket*

**3.1** The Review Panel recommended the use of mean intake values from the Dabeka and McKenzie (1995) data for estimating exposures to nickel from the normal diet.

**3.1.1** In the Panel's view, upper bound intake values from short-term food consumption surveys may not provide an appropriate estimate of typical long-term food consumption patterns, and the OMOE use of a mean value was appropriate.

*Response:No action required.*

**3.1.2** The Dabeka data have been peer-reviewed and published, and represents the author's analysis and conclusions. However, the Panel recognised that the Dabeka data are from one study from the city of Montreal, and may not be fully representative of dietary habits of the Port Colborne population. These uncertainties should be communicated within the uncertainty section of the revised document.

*Response: Addressed in section 6.2 (Main document).*

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**3.1.3** Studies from other jurisdictions (*e.g.*, the U.S. and U.K. market intake surveys) show lower intake of nickel from foods. This provides confidence that the nickel intake from diet would not be underestimated in this assessment.

*Response: Addressed in section 6.2 (Main document).*

**3.2** The potential reasons for the reported differences between available studies on the Food Basket data on nickel should be discussed in greater detail, particularly the impacts of the use of different cooking utensils and vessels on metal content in foods during preparation/cooking, as well as variation in analytical laboratory methodologies and detection limits. The procedures used to address non-detect nickel concentrations reported in produce need to be investigated and discussed as appropriate in the report.

*Response: Addressed in Appendix 4 (section A4-2.3). The treatment of non-detect values has not been addressed in this draft. This issue is being addressed.*

**3.3** Infant consumption rates for market basket foods should not be based on a proportionate adjustment of adult intake information as conducted by CEPA (1994). The Panel recommended using a more age-appropriate infant diet, as presented by the OMOE in the discussion of alternatives within the draft document.

*Response: Addressed in Appendix 4 (section A4-2.3). It should be noted that the CEPA infant diet is not derived from adult intake data, but is based on 1970s infant intake survey data.*

*Home Garden*

**3.4** The discussion of home grown produce consumption values needs to be expanded and the uncertainty of the various estimates presented. For example, the home-grown produce consumption rate of 9.9% of total produce that was used is higher than those observed in other jurisdictions. These issues should be addressed in the sensitivity analysis, and discussed in the section on strengths and uncertainty of the assessment.

*Response: Addressed in section 6.3 (Main document) and Appendix 6 (section A6-7).*

**3.5** There is insufficient data to support the use of a linear regression to calculate a soil-to-plant uptake factor for nickel. Rather, the Panel recommended that the Ministry re-evaluate the available data and select an appropriate upper bound value for plant uptake of nickel.

*Response: Addressed in Appendix 3 (section A3-1.4).*

**3.6** There are a number of different fruits listed in the "vegetable" nickel analyses table (page 12 of Appendix 1). The data should be re-evaluated to determine whether fruits, in addition to vegetables, were present in the home gardens found in the Rodney Street community.

*Response: Addressed in Appendix 3 (section A3-1.4).*

**3.7** It is likely overly conservative to have potential consumption of home garden produce, in addition to full daily consumption from market basket (*i.e.*, background). The Panel recommends adjusting the market produce consumption rate by the home garden produce consumption, to avoid double counting and exceeding the overall typical daily fruit/vegetable consumption.

*Response: Market basket intakes were not adjusted for home grown produce because the use of an upper bound plant tissue nickel concentration from all the aggregated produce types precludes a detailed accounting of the intake of each produce type from either source.*

**3.8** It should be noted in the report that very few of the residences in the Rodney Street area have home gardens. However, the Panel agrees with the inclusion of this pathway so that the assessment may be sufficiently conservative to enable residents to consume home grown garden produce.

*Response: Addressed in Appendix 3 (section A3-1.4).*

## 4. Dermal Contact (Contact Dermatitis and Impacts of Oral Intake)

**4.1** The discussion of nickel-induced contact dermatitis within the assessment report needs to be expanded. The discussion should emphasize that higher levels of exposure are necessary to cause sensitization to nickel than to elicit a response in a sensitized individual. This is a common feature of chemical sensitization in general. However, the available information is inadequate to estimate the magnitude of nickel exposures that could cause sensitization.

*Response: Addressed in Appendix 2 (section A2-9.2.4).*

**4.2** The discussion of contact dermatitis should emphasize that contact of sensitized individuals with nickel-contaminated soils has the potential to cause contact dermatitis. The assessment should indicate that the available information does not enable the identification of a soil nickel concentration that would result in contact dermatitis. Evidence of the low levels of exposure that are needed to cause contact dermatitis from other agents should be summarized to support the conclusion that protection of sensitized individuals by limiting soil nickel concentrations may not be practically achievable.

*Response: Addressed in section 7.1 (Main document).*

**4.3** The East Side Community Health Study, to be conducted over the next 8 to 10 months, will be testing people living in the Rodney Street Community for nickel contact dermatitis. The results of this study may provide information on the extent and degree of concern on this issue.

*Response: Not addressed in this draft. This information is not available yet.*

## 5. Indoor/Outdoor Dust Exposures

**5.1** The MOE risk assessment treated indoor dust as comparable to outdoor soil. It would be preferable to treat indoor dust as a separate exposure media with distinct characteristics.

*Response: In the absence of reliable information on metal concentrations in indoor dust, the contribution of outdoor soil to indoor dust was modeled using literature values (section A6-5.2).*

**5.2** The use of the 10% winter soil cover adjustment to soil ingestion rates and dermal exposures is not considered appropriate for estimating nickel exposure from indoor dust. The Panel recommends removing this adjustment, and include a discussion of the conservatism involved in using the same indoor dust exposure year-round.

*Response: Done, discussed in section 6.2 (Main document).*

5.3 The relative bioavailability of nickel from outdoor soil and indoor dust required additional discussion. Very little information on this topic is available. One study indicated that bioavailability of dust was slightly higher than that of outdoor soil. This issue requires further discussion in the uncertainty section.

*Response: Addressed in section 6.2 (Main document).*

5.4 The occurrence of indoor dust reservoirs in inaccessible areas of homes requires additional discussion. Remediation of outdoor soil may not immediately affect indoor dust reservoirs, arising from historical air emissions.

*Response: Addressed in section 6.2 (Main document).*

5.5 If these indoor dust reservoirs are not disturbed (*i.e.*, extensive renovations), one would not expect indoor dust concentrations to be significantly elevated. Although events such as renovations may result in an elevation of ambient concentrations of nickel of indoor air and dust, one would expect this to only result in the potential for short-term exposure. As these exposures would only be short-term and are expected to occur infrequently, it would be inappropriate to include in the overall risk assessment.

*Response: Addressed in section 6.2 (Main document).*

5.6 In the current risk assessment, indoor dust levels were considered to be 39.5% of the outdoor soil level. Available data do indicate that at sites without a significant air source of metals, indoor dust concentrations are generally less than outdoor soil concentrations. However, additional justification should be provided for the value used in the current risk assessment.

*Response: Addressed in Appendix 6 (section A6-5.2).*

## 6. Other Metals

6.1 The toxicology discussion of cadmium should reference the association between cadmium exposure and osteoporosis. Further information can be found in the following articles:

Järup, L. *et al*. 1999. Cadmium may be a risk factor for osteoporosis. Occup Environ Med 55:435-439.
Staessen, J.A. *et al*. 1999. Environmental exposure to cadmium, forearm bone density, and risk of fractures: prospective population study. Lancet 353.

*Response: Addressed in Appendix 6 (section A6-5.2).*

6.2 The toxicology discussion of antimony should be expanded based upon the new NRC study. The new study is considered more appropriate for exposure from environmental sources. However, antimony was not an issue using the lower exposure criteria. Therefore, the current assessment has an extra margin of safety.

*Response: Addressed in Appendix 2 (section A2-2.3.1).*

**6.3** The section on the toxicology of lead should reference the polymorphism of delta-aminolevulinic acid dehydrogenase. Further information can be found in the following articles:

Gerhardsson, L. *et al*. 1999. Chelated lead in Relation to Lead in Bone and ALAD Genotype. Environ Res Section A 80:389-398.
Landrigan, P.J. *et al*. 2000. The Reproductive Toxicity and Carcinogenicity of Lead: A Critical Review. Am J Ind Med 38:231-243.

*Response: Addressed in Appendix 2 (section A2-8.1).*

## 7. Bioavailability

**7.1** While the Panel concluded that the bioavailability adjustments in the assessment were appropriately conducted, the documentation in Appendix 5 requires further clarification of the concept of relative bioavailability in the context of risk assessment.

*Response:Done (see Appendix 2 (section A2-1).*

**7.2** It is recommended that future work on bioavailability should be based on unground soil samples sieved to <250 microns. This approach would ensure that particles so large that they would not adhere to skin, and thus would be unlikely to be ingested, would be removed from the assessment.

*Response: Standard MOE SOP is sieving to <350 microns. Changes in our SOP will be considered in future investigations.*

## 8. Uncertainty Discussion

The discussion of the strengths and uncertainties of the Revised 2001 HHRA Study communicates important information to the reader on the degree of confidence in the final soil intervention level for nickel. Therefore, the International Review Panel identified the following issues that could be addressed to improve the overall discussion of uncertainty within the report.

**8.1** The Panel recommends that the discussion of uncertainty and variability, and the distinction between the two, be clarified. This can be achieved by creating a table that identifies the critical parameters that have uncertainty associated with them, the magnitude/impact of the uncertainty associated with these parameters, and the rationale for the magnitude of the impacts on assessment results.

*Response: Addressed in section 6.1 (Main document).*

**8.2** The report should present a table that identifies the critical parameters that have uncertainty associated with them, the magnitude/impact of the uncertainty associated with these parameters, and the rationale for the magnitude of the impacts on assessment results.

*Response: A table indicating the impact of changing model parameters as compared with our March 2001 model is included in today's package. This could be the basis for addressing this issue.*

**8.3** **A quantitative sensitivity analysis should be conducted to evaluate the relative impact of selected critical parameter on the overall assessment results and conclusions.**

*Response: See response to 8.2 above.*